Measurement of RF Interference from a 100-00 Liquid Level Sensor Transceiver

For	Creative Electronics and Software, Inc. 650 Sundown Road South Elgin, IL 60177
P.O. Number	06071973
Date Tested	June 21-26, 2019
Test Personnel	Javier Cardenas
Specification	FCC "Code of Federal Regulations" Title 47, Part 15, Subpart C, Section 15.247 for Digital Modulation Intentional Radiators Operating within the bands 902-928MHz and 2400-2483.5MHz, FCC “Code of Federal Regulations” Title 47, Part15, Subpart 15B, 15.109 Industry Canada RSS-247 ICES-003

Test Report By:

Javier Cardenas
EMC Engineer

Requested By:

Matt Williams
Creative Electronics and Software, Inc.

Approved By:

Raymond J. Klouda
Registered Professional
Engineer of Illinois - 44894

Elite Electronic Engineering Inc.
1516 CENTRE CIRCLE
DOWNERS GROVE, IL 60515

TEL: 630 - 495 - 9770
FAX: 630 - 495 - 9785

www.elitetest.com

TABLE OF CONTENTS

PARAGRAPH	DESCRIPTION OF CONTENTS	PAGE NO.
1.	INTRODUCTION	5
1.1	Scope of Tests	5
1.2	Purpose	5
1.3	Deviations, Additions and Exclusions	5
1.4	EMC Laboratory Identification	5
1.5	Laboratory Conditions	5
2.	**APPLICABLE DOCUMENTS**	5
3.	**EUT SET-UP AND OPERATION**	6
3.1	General Description	6
3.1.1	Power Input	6
3.1.2	Peripheral Equipment	6
3.1.3	Grounding	6
3.2	Operational Mode	6
3.3	EUT Modifications	6
4.	**TEST FACILITY AND TEST INSTRUMENTATION**	6
4.1	Shielded Enclosure	6
4.2	Test Instrumentation	7
4.3	Calibration Traceability	7
4.4	Measurement Uncertainty	7
5.	**TEST PROCEDURES**	7
5.1	Radiated Measurements	7
5.1.1	Requirements	7
5.1.2	Procedures	8
5.1.3	Results	9
5.2	Transmitter	9
5.2.1	DTS 6dB Bandwidth	9
5.2.1.1	Requirements	9
5.2.1.2	Procedures	9
5.2.1.3	Results	9
5.2.2	Peak Output Power	9
5.2.2.1	Requirements	9
5.2.2.2	Procedures	9
5.2.2.3	Results	10
5.2.3	Duty Cycle Factor Measurements	10
5.2.3.1	Procedures	10
5.2.3.2	Results	10
5.2.4	Radiated Spurious Emissions Measurements	10
5.2.4.1	Requirements	10
5.2.4.2	Procedures	11
5.2.4.3	Results	12
5.2.5	Band Edge Compliance	12
5.2.5.1	Requirements	12
5.2.5.2	Procedures	12
5.2.5.2.1	Low Band Edge	12
5.2.5.2.2	High Band Edge	13
5.2.5.2.3	Low Band Edge	13
5.2.5.2.4	High Band Edge	13
5.2.5.3	Results	14

THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF ELITE ELECTRONIC ENGINEERING INCORPORATED.

5.2.6 Power Spectral Density 14
5.2.6.1 Requirement 14
5.2.6.2 Procedures 14
Results 14
6. CONCLUSIONS 14
7. CERTIFICATION 14
8. ENDORSEMENT DISCLAIMER 15
9. EQUIPMENT LIST 16
Table 9-1 Equipment List 16

THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF ELITE ELECTRONIC ENGINEERING INCORPORATED.

REVISION HISTORY

Revision	Date	Description
—	28 June 2019	Initial release
A	8 July 8, 2019	The following changes were made: - Power Spectral Density data revised on pg113 and pg115 - Section 3.3 was modified to mention that there was no modification to the EUT - “Rev A” was added to the header throughout the report

Measurement of RF Emissions from a Liquid Level Sensor, Part No. 100-00 Transceiver

1. INTRODUCTION

1.1 Scope of Tests

This document represents the results of the series of radio interference measurements performed on a Creative Electronics and Software, Inc. Liquid Level Sensor, Part No. 100-00, Serial No. 0009018523, transceiver (hereinafter referred to as the EUT). The EUT is a digital modulation transceiver. The transceiver was designed to transmit and receive in the 902-928 MHz and 2400-2483.5 MHz, bands using an internal antenna. The EUT contained a direct conversion receiver. The EUT was manufactured and submitted for testing by Creative Electronics and Software, Inc. located in South Elgin, IL.

1.2 Purpose

The test series was performed to determine if the EUT meets radiated RF emissions requirements, and additional provisions of the FCC "Code of Federal Regulations" Title 47, Part 15, Subpart B, Section 15.109 for a class A digital devices, and Subpart C, Section 15.247 for Intentional Radiators Operating within the 902-928 MHz and 2400-2483.5 MHz bands.

The test series was also performed to determine if the EUT meets the radiated RF emission requirements of the Industry Canada, ICES-003 Section 6.2 for Class A Information Technology Equipment (ITE) and Industry Canada Radio Standards Specification RSS-247 for Transmitters.

Testing was performed in accordance with ANSI C63.4-2014 and ANSI C63.10-2013.

1.3 Deviations, Additions and Exclusions

There were no deviations, additions to, or exclusions from the test specification during this test series.

1.4 EMC Laboratory Identification

This series of tests was performed by Elite Electronic Engineering Incorporated of Downers Grove, Illinois. The laboratory is accredited by the American Association for Laboratory Accreditation (A2LA), A2LA Lab Code: 1786-01.

1.5 Laboratory Conditions

The temperature at the time of the test was 21°C and the relative humidity was 22%.

2. APPLICABLE DOCUMENTS

The following documents of the exact issue designated form part of this document to the extent specified herein:

- Federal Communications Commission "Code of Federal Regulations", Title 47, Part 15, Subparts B and C

- ANSI C63.4-2014, "American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz”

- ANSI C63.10-2013, "American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices”

- Federal Communications Commission Office of Engineering and Technology Laboratory Division, Guidance For Performing Compliance Measurements On Digital Transmissions Systems (DTS) Operating Under §15.247
  April 2, 2019

- Industry Canada RSS-247, Issue 2, February 2017, “Spectrum Management and Telecommunications Radio Standards Specification, Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs), and License-Exempt Local Area Network (LE-LAN) Devices”

- ICES-003, Issue 6, January 2016, “Spectrum Management and Telecommunications, Interference-Causing Equipment Standard, Information Technology Equipment (Including Digital Apparatus) – Limits and methods of measurement”

3. EUT SET-UP AND OPERATION

3.1 General Description

The EUT is a Liquid Level Sensor, Part No. 100-00. A block diagram of the EUT setup is shown as Figure 1 and Figure 2.

3.1.1 Power Input

The EUT was powdered by 3.3Vdc from internal batteries.

3.1.2 Peripheral Equipment

The following peripheral equipment was submitted with the EUT:

Item	Description
Laptop	Used to configure the EUT into the appropriate mode of operation

3.1.3 Grounding

The EUT was ungrounded during the tests.

3.2 Operational Mode

The EUT and all peripheral equipment were energized. The unit was programmed to operate in one of the following modes:

BLE
- Transmit at 2402MHz
- Transmit at 2440MHz
- Transmit at 2480MHz

LoRA
- Transmit at 903MHz, SF8
- Transmit at 909.4MHz, SF8
- Transmit at 914.2MHz, SF8

- Idle

3.3 EUT Modifications

There were no modifications made to the EUT.

4. TEST FACILITY AND TEST INSTRUMENTATION

4.1 Shielded Enclosure

All tests were performed in a 32ft. x 20ft. x 18ft. hybrid ferrite-tile/anechoic absorber lined test chamber. With the exception of the floor, the reflective surfaces of the shielded chamber are lined with ferrite tiles on the walls and ceiling. Anechoic absorber material is installed over the ferrite tile. The floor of the chamber is used as the ground plane. The chamber complies with ANSI C63.4-2014 for site attenuation.

4.2 Test Instrumentation

The test instrumentation and auxiliary equipment used during the tests are listed in Table 9-1. All equipment was calibrated per the instruction manuals supplied by the manufacturer.

Conducted and radiated emission tests were performed with an EMI receiver utilizing the bandwidths and detectors specified by the FCC.

4.3 Calibration Traceability

Test equipment is maintained and calibrated on a regular basis. All calibrations are traceable to the National Institute of Standards and Technology (NIST).

4.4 Measurement Uncertainty

All measurements are an estimate of their true value. The measurement uncertainty characterizes, with a specified confidence level, the spread of values which may be possible for a given measurement system.

Values of Expanded Measurement Uncertainty (95% Confidence) are presented below:

Measurement Type	Expanded Measurement Uncertainty
Conducted disturbance (mains port) (150 kHz – 30 MHz)	2.7
Radiated disturbance (electric field strength on an open area test site or alternative test site) (30 MHz – 1000 MHz)	4.3
Radiated disturbance (electric field strength on an open area test site or alternative test site) (1 GHz – 6 GHz)	3.1
Radiated disturbance (electric field strength on an open area test site or alternative test site) (6 GHz – 18 GHz)	3.2

5. TEST PROCEDURES

5.1 Unintentional Radiated Emission Measurements

5.1.1 Requirements

All emanations from a Class A device shall be below the levels shown in the following tables:

RADIATION LIMITS BELOW 1GHz FOR CLASS A DEVICE

Frequency MHz	Distance between EUT And Antenna in Meters	Field Strength Limit Quasi-Peak uV/m	Field Strength Limit Quasi-Peak dBuV/m
30-88	10	90	39
88-216	10	150	43.5
216-960	10	210	46.4
960-1000	10	300	49.5

Note 1: The tighter limit shall apply at the edge between the two frequency bands.
Note 2: Measurements taken with a 120kHz Bandwidth.

RADIATION LIMITS ABOVE 1GHz FOR CLASS A DEVICE

Frequency MHz	Distance between EUT And Antenna in Meters	Field Strength Limit Peak uV/m	Field Strength Limit Peak dBuV/m	Field Strength Limit Average uV/m	Field Strength Limit Average dBuV/m
>1000	10	3000	69.5	300	49.5

Note 1: Measurements taken with a 1MHz Bandwidth.

5.1.2 Procedures

All tests were performed in a 32ft. x 20ft. x 18ft. hybrid ferrite-tile/anechoic absorber lined test chamber. The walls and ceiling of the shielded chamber are lined with ferrite tiles. Anechoic absorber material is installed over the ferrite tile. The floor of the chamber is used as the ground plane. The chamber complies with ANSI C63.4-2014 for site attenuation.

The shielded enclosure prevents emissions from other sources, such as radio and TV stations from interfering with the measurements. All powerlines and signal lines entering the enclosure pass through filters on the enclosure wall. The powerline filters prevent extraneous signals from entering the enclosure on these leads.

Since a quasi-peak detector and an average detector requires a long integration times, it is not practical to automatically sweep through the quasi-peak and average levels. Therefore, radiated emissions from the EUT were first scanned using a peak detector and automatically plotted. The frequencies where significant emission levels were noted were then remeasured using the quasi-peak detector or average detector.

The broadband measuring antenna was positioned at a 3 meter distance from the EUT. The frequency range from 30MHz to 1GHz was investigated using a peak detector function with the bilog antenna at several heights, horizontal and vertical polarization, and with several different orientations of the EUT with respect to the antenna. The frequency range from 1GHz to 12.5GHz was investigated using a peak detector function with the double ridged waveguide antenna at several heights, horizontal and vertical polarization, and with several different orientations of the EUT with respect to the antenna. The data was then processed by the computer to equivalent field intensity at 10 meters using linear extrapolation. A -10.5dB (-10.5dB = 20 * Log (3m/10m)) distance correction factor has automatically been applied to the plotted emissions data. The maximum levels for each antenna polarization were plotted. The resultant field strength (FS) is a summation in decibels (dB) of the receiver meter reading (MTR), the antenna correction factor (AF), and the cable loss factor (CF). If an external preamplifier is used, the total is reduced by its gain (-PA). If a distance correction (DC) is required, it is added to the total.

Formula 1: FS (dBuV/m) = MTR (dBuV) + AF (dB/m) + CF (dB) + (- PA (dB)) + DC (dB)

To convert the Field Strength dBuV/m term to uV/m, the dBuV/m is first divided by 20. The Base 10 AntiLog is taken of this quotient. The result is the Field Strength value in uV/m terms.

Formula 2: FS (uV/m) = AntiLog [(FS (dBuV/m))/20]

Final radiated emissions were performed on all significant broadband and narrowband emissions found in the exploratory sweeps using the following methods:

1) Measurements from 30MHz to 1GHz were made using a quasi-peak detector and a broadband bilog antenna. Measurements above 1GHz were made using a peak detector and an average detector and a broadband double ridged waveguide antenna.
2) To ensure that maximum or worst case, emission levels were measured, the following steps were taken:
    a) The EUT was rotated so that all of its sides were exposed to the receiving antenna.
    b) Since the measuring antenna is linearly polarized, both horizontal and vertical field components were measured.

c) The measuring antenna was raised and lowered from 1 to 4 meters for each antenna polarization to maximize the readings.

d) For hand-held or body-worn devices, the EUT was rotated through three orthogonal axes to determine which orientation produces the highest emission relative to the limit.

5.1.3 Results

The exploratory peak radiated emission plots and final radiated emissions tabular data from 30MHz to 12.5GHz are presented on pages 21 through 26.

As can be seen from the data, all emissions measured from the EUT met the quasi-peak limit below 1GHz and met both the peak limit and average limit above 1GHz. Photographs of the test configuration which yielded the highest or worst case, radiated emission levels are shown in Figure 3 and Figure 4.

5.2 Transmitter

5.2.1 DTS 6dB Bandwidth

5.2.1.1 Requirements

Per 15.247(a)(2),the minimum 6dB bandwidth shall be at least 500kHz for all systems using digital modulation techniques.

5.2.1.2 Procedures

The antenna port of the EUT was connected to the spectrum analyzer through 10dB of attenuation for BLE and 30dB for LoRA.

The EUT was allowed to transmit continuously. The transmit channel was set separately to low, middle, and high channels. The resolution bandwidth (RBW) was set to 100kHz, the video bandwidth (VBW) was set to the same as or 3 times greater than the RBW, and the span was set to 3 times the RBW.

The 'Max-Hold' function was engaged. The analyzer was allowed to scan until the envelope of the transmitter bandwidth was defined. The analyzer's display was plotted using a 'screen dump' utility.

5.2.1.3 Results

The plots on pages 30 through 41 show that the minimum 6 dB bandwidth was 664.3kHz for BLE and 659.3kHz for LoRA which is greater than the minimum allowable 6dB bandwidth requirement of 500kHz for systems using digital modulation techniques. The 99% bandwidth was measured to be 1.06MHz for BLE and 697.2kHz for LoRA.

5.2.2 Peak Output Power

5.2.2.1 Requirements

Per section 15.247(b)(3), for systems using digital modulation the maximum peak output conducted power shall not be greater than 1.0W (30dBm). Per section 15.247(b)(4), this limit is based on the use of antennas with directional gains that do not exceed 6dBi. Since the limit allows for a 6dBi antenna gain, the maximum EIRP can be increased by 6dB to 4 Watt (36dBm).

5.2.2.2 Procedures

The antenna port of the EUT was connected to the spectrum analyzer through 10dB of attenuation for BLE and 30dB for LoRA. The EUT was set to transmit separately at the low, middle, and high channels. The resolution bandwidth (RBW) was set to greater than the 6dB bandwidth. The 'Max-Hold' function was engaged. The maximum meter reading was recorded. The peak power output was calculated for the low, middle and high channels.

5.2.2.3 Results

The results are presented on pages 42 through 53. The maximum peak conducted output power from the BLE transmitter was 0.89mW (-0.52dBm) which is below the 1 Watt limit. The maximum peak conducted output power from the LoRA transmitter was 42.5mW (16.29dBm) which is below the 1 Watt limit.

The maximum EIRP from the BLE transmitter was 0.42mW (-3.8dBm) which is below the 4 Watt limit. The maximum EIRP from the LoRA transmitter was 141.3mW (21.5dBm) which is below the 4 Watt limit.

5.2.3 Duty Cycle Factor Measurements

5.2.3.1 Procedures

The duty cycle factor is used to convert peak detected readings to average readings. This factor is computed from the time domain trace of the pulse modulation signal.

With the transmitter set up to transmit for maximum pulse density, the time domain trace is displayed on the spectrum analyzer. This trace is obtained by tuning center frequency to the transmitter frequency and then setting a zero span width with 10msec/div (adjust this for what you need). The amplitude settings are adjusted so that the on/off transitions clear the 4th division from the bottom of the display. The markers are set at the beginning and end of the “on-time”. The trace is recorded.

Next, the spectrum analyzer center frequency is set to the transmitter frequency with a zero span width and 10msec/div. This shows if the word is longer than 100msec or shorter than 100msec. If the word period is less than 100msec, the display is set to show at least one word. The on-time and off-time are then measured. The on-time is total time signal level exceeds the 4th division. Off-time is time under for the word period. The duty cycle is then computed as the (On-time/ word period) where the word period = (On-time + Off-time).

5.2.3.2 Results

The plots and calculation of the duty cycle are shown on data page 54. The duty cycle factor was 10.96dB.

5.2.4 Radiated Spurious Emissions Measurements

5.2.4.1 Requirements

Per section 15.247(d), in any 100kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated emissions measurement. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must comply with the radiated emission limits specified in §15.209(a).

Radiated emissions which fall in the restricted bands, as defined in §15.205(a), must comply with the radiated emission limits specified in §15.209(a).

Paragraph 15.209(a) has the following radiated emission limits:

Frequency MHz	Field Strength (microvolts/meter)	Measurement distance (meters)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	3
30.0-88.0	100	3
88.0-216.0	150	3
216.0-960.0	200	3
Above 960	500	3

5.2.4.2 Procedures

Radiated measurements were performed in a 32ft. x 20ft. x 14ft. high shielded enclosure. The shielded enclosure prevents emissions from other sources, such as radio and TV stations from interfering with the measurements. All powerlines and signal lines entering the enclosure pass through filters on the enclosure wall. The powerline filters prevent extraneous signals from entering the enclosure on these leads.

Preliminary radiated emissions tests were performed to determine the emission characteristics of the EUT. For the preliminary test, a broadband measuring antenna was positioned at a 3 meter distance from the EUT. The entire frequency range from 30MHz to 10.0GHz (for 902-928MHz LoRA) and 30MHz to 26.5GHz (for 2400-2483.5Mhz BLE) was investigated using a peak detector function.

The final open field emission tests were then manually performed over the frequency ranges.

1) For all harmonics not in the restricted bands, the following procedure was used:
   a) The field strength of the fundamental was measured using a double ridged waveguide antenna (bilog antenna for LoRA 902-928MHz). The waveguide antenna (bilog antenna) was positioned at a 3 meter distance from the EUT. The EUT was placed on a 1.5 meter high (80cm high for LoRA) non-conductive stand. A peak detector with a resolution bandwidth of 100 kHz was used on the spectrum analyzer.
   b) The field strengths of all of the harmonics not in the restricted band were then measured using a double-ridged waveguide antenna. The waveguide antenna was positioned at a 3 meter distance from the EUT. The EUT was placed on a 1.5 meter high non-conductive stand. A peak detector with a resolution bandwidth of 100 kHz was used on the spectrum analyzer.
   c) To ensure that maximum or worst case emission levels at the fundamental and harmonics were measured, the following steps were taken when measuring the fundamental emissions and the spurious emissions:
      i) The EUT was rotated so that all of its sides were exposed to the receiving antenna.
      ii) Since the measuring antenna is linearly polarized, both horizontal and vertical field components were measured.
      iii) The measuring antenna was raised and lowered for each antenna polarization to maximize the readings.
      iv) In instances where it was necessary to use a shortened cable between the measuring antenna and the spectrum analyzer. The measuring antenna was not raised or lowered to ensure maximized readings, instead the EUT was rotated through all axis to ensure the maximum readings were recorded for the EUT.
   d) All harmonics not in the restricted bands must be at least 20 dB below levels measured at the fundamental. However, attenuation below the general limits specified in §15.209(a) is not required.
2) For all emissions in the restricted bands, the following procedure was used:
   a) The field strengths of all emissions below 1 GHz were measured using a bi-log antenna. The bi-log antenna was positioned at a 3 meter distance from the EUT. The EUT was placed on an 80cm high non-conductive stand. A peak detector with a resolution bandwidth of 100 kHz was used on the spectrum analyzer.
   b) The field strengths of all emissions above 1 GHz were measured using a double-ridged waveguide antenna. The waveguide antenna was positioned at a 3 meter distance from the EUT. The EUT was placed on a 1.5 meter high non-conductive stand. A peak detector with a resolution bandwidth of 1 MHz was used on the spectrum analyzer.
   c) To ensure that maximum or worst case emission levels were measured, the following steps were taken when taking all measurements:
      i) The EUT was rotated so that all of its sides were exposed to the receiving antenna.

ii) Since the measuring antenna is linearly polarized, both horizontal and vertical field components were measured.

iii) The measuring antenna was raised and lowered for each antenna polarization to maximize the readings.

iv) In instances where it was necessary to use a shortened cable between the measuring antenna and the spectrum analyzer. The measuring antenna was not raised or lowered to ensure maximized readings, instead the EUT was rotated through all axis to ensure the maximum readings were recorded for the EUT.

d) For all radiated emissions measurements below 1 GHz, if the peak reading is below the limits listed in 15.209(a), no further measurements are required. If however, the peak readings exceed the limits listed in 15.209(a), then the emissions are remeasured using a quasi-peak detector.

e) For all radiated emissions measurements above 1 GHz, the peak readings must comply with the 15.35(b) limits. 15.35(b) states that when average radiated emissions measurements are specified, there also is a limit on the peak level of the radiated emissions. The limit on the peak radio frequency emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test. Therefore, all peak readings above 1 GHz must be no greater than 20 dB above the limits specified in 15.209(a).

f) Next, for all radiated emissions measurements above 1GHz, the resolution bandwidth was set to 1MHz. The analyzer was set to linear mode with a 10Hz video bandwidth in order to simulate an average detector. An average reading was taken.

5.2.4.3 Results

Preliminary radiated emissions plots with the EUT transmitting at Low Frequencies, Middle Frequencies, and High Frequencies are shown on pages 55 through 90. Final radiated emissions data are presented on data pages 91 through 108. As can be seen from the data, all emissions measured from the EUT were within the specification limits. Photographs of the test configuration which yielded the highest, or worst case, radiated emission levels are shown in Figures 5 through 7.

5.2.5 Band Edge Compliance

5.2.5.1 Requirements

Per section 15.247(d), the emissions at the band edges must be at least 20dB below the highest level measured within the band but attenuation below the general limits listed in 15.209(a) is not required.

5.2.5.2 Procedures

For LoRA 902-928MHz:

5.2.5.2.1 Low Band Edge

1) The antenna port of the EUT was connected to the spectrum analyzer through 30dB of attenuation.
2) The EUT was set to transmit continuously at the channel closest to the low band edge.
3) To determine the band edge compliance, the following spectrum analyzer settings were used:

   a. Center frequency = low band edge frequency.
   b. Span = Wide enough to capture the peak level of the emission operating on the channel closest to the band edge, as well as any modulation products which fall outside of the authorized band of operation.
   c. Resolution bandwidth (RBW) ≥ 1% of the span.
   d. The 'Max-Hold' function was engaged. The analyzer was allowed to scan until the envelope of the transmitter bandwidth was defined.
   e. The marker was set on the peak of the in-band emissions. A display line was placed 20dB down from the peak of the in-band emissions. All emissions which fall outside of the authorized band of operation must be below the 20dB down display line. (All emissions to

the left of the center frequency (band edge) must be below the display line.)

f. The analyzer's display was plotted using a 'screen dump' utility.

5.2.5.2.2 High Band Edge

1) The antenna port of the EUT was connected to the spectrum analyzer through 40dB of attenuation.
2) The EUT was set to transmit continuously at the channel closest to the high band edge.
3) To determine the band edge compliance, the following spectrum analyzer settings were used:

g. Center frequency = high band edge frequency.
h. Span = Wide enough to capture the peak level of the emission operating on the channel closest to the band edge, as well as any modulation products which fall outside of the authorized band of operation.
i. Resolution bandwidth (RBW) ≥ 1% of the span.
j. The 'Max-Hold' function was engaged. The analyzer was allowed to scan until the envelope of the transmitter bandwidth was defined.
k. The marker was set on the peak of the in-band emissions. A display line was placed 20dB down from the peak of the in-band emissions. All emissions which fall outside of the authorized band of operation must be below the 20dB down display line. (All emissions to the right of the center frequency (band edge) must be below the display line.)
l. The analyzer's display was plotted using a 'screen dump' utility.

For BLE 2400-2483.5MHz SYSTEMS:

5.2.5.2.3 Low Band Edge

1) The antenna port of the EUT was connected to the spectrum analyzer through 10dB of attenuation.
2) The EUT was set to transmit continuously at the channel closest to the low band edge.
3) To determine the band edge compliance, the following spectrum analyzer settings were used:

a. Center frequency = low band edge frequency.
b. Span = Wide enough to capture the peak level of the emission operating on the channel closest to the band edge, as well as any modulation products which fall outside of the authorized band of operation.
c. Resolution bandwidth (RBW) ≥ 1% of the span.
d. The 'Max-Hold' function was engaged. The analyzer was allowed to scan until the envelope of the transmitter bandwidth was defined.
e. The marker was set on the peak of the in-band emissions. A display line was placed 20dB down from the peak of the in-band emissions. All emissions which fall outside of the authorized band of operation must be below the 20dB down display line. (All emissions to the left of the center frequency (band edge) must be below the display line.)
f. The analyzer's display was plotted using a 'screen dump' utility.

5.2.5.2.4 High Band Edge

1) The EUT was set to transmit continuously at the channel closest to the high band edge.
2) A double ridged waveguide was placed 3 meters away from the EUT. The antenna was connected to the input of a spectrum analyzer.
3) The center frequency of the analyzer was set to the high band edge (2483.5MHz)
4) The resolution bandwidth was set to 1MHz.
5) To ensure that the maximum or worst case emission level was measured, the following steps were taken:

a. The EUT was rotated so that all of its sides were exposed to the receiving antenna.
b. Since the measuring antenna is linearly polarized, both horizontal and vertical field

components were measured.

c. The measuring antenna was raised and lowered from 1 to 4 meters for each antenna polarization to maximize the readings.

6) The highest measured peak reading was recorded.
7) The highest measured average reading was recorded.

5.2.5.3 Results

Pages 109 through 112 show the conducted and radiated band edge compliance results. As can be seen from these plots, the emissions at the low end band edge and the high end band edge are within the 20 dB. For BLE the high end band edge is below the general limits.

5.2.6 Power Spectral Density

5.2.6.1 Requirement

Per section 15.247(e), the peak power spectral density from the intentional radiator shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

5.2.6.2 Procedures

1) The antenna port of the EUT was connected to the spectrum analyzer through a 10dB pad for BLE and a 30dB pad for LoRA.
2) The EUT was then placed in the normal operation mode (for DTS devices)
3) To determine the power spectral density, the following spectrum analyzer settings were used:
   a. Center frequency = transmit frequency
   b. Span = 1.5 times the DTS (6 dB) bandwidth
   c. Resolution bandwidth (RBW): 3kHz ≤ RBW ≤ 100kHz
   d. Sweep time = auto
   e. The peak detector and 'Max-Hold' function was engaged.
   f. The display line represents the 8 dBm limit
   g. The analyzer's display was plotted using a 'screen dump' utility.

4) If measured value exceeds limit, reduce RBW (no less than 3kHz) and repeat.

Results

Pages 113 through 118 show the power spectral density results. As can be seen from this plot, the peak power density is less than 8dBm in a 3kHz band during any time interval of continuous transmission.

6. CONCLUSIONS

It was determined that the Creative Electronics and Software, Inc. Liquid Level Sensor, Part No. 100-00 digital modulation transceiver, Serial No. 0009018523, did fully meet the radiated emission requirements of the FCC "Code of Federal Regulations" Title 47, Part 15, Subpart B, 15.109 and Subpart C, Section 15.247 for Intentional Radiators Operating within the 902-928 MHz and 2400-2483.5 MHz bands, when tested per ANSI C63.4-2014.

It was also determined that the Creative Electronics and Software, Inc. Liquid Level Sensor, Part No. 100-00 digital modulation transceiver, Serial No. 0009018523, did fully meet the radiated interference requirements of Section 6.2 of the Industry Canada ICES-003 for Class A Information Technology Equipment (ITE) and the Industry Canada Radio Standards Specification RSS-247 for transmitters, when tested per ANSI C63.4-2014.

7. CERTIFICATION

Elite Electronic Engineering Incorporated certifies that the information contained in this report was obtained under conditions which meet or exceed those specified in the test specifications.

The data presented in this test report pertains to the EUT at the test date. Any electrical or mechanical

modification made to the EUT subsequent to the specified test date will serve to invalidate the data and void this certification.

8. ENDORSEMENT DISCLAIMER

This report must not be used to claim product certification, approval, or endorsement by A2LA, NIST or any agency of the Federal Government.

9. EQUIPMENT LIST

Table 9-1 Equipment List

Eq ID	Equipment Description	Manufacturer	Model No.	Serial No.	Frequency Range	Cal Date	Due Date
APW3	PREAMPLIFIER	PLANAR ELECTRONICS	PE2-35-120-5R0-10-12	PL2924	1GHZ-20GHZ	4/8/2019	4/8/2020
CDY0	WORKSTATION	ELITE	WORKSTATION		WINDOWS 7	N/A	
GSF0	VECTOR SIGNAL GENERATOR	ROHDE & SCHWARZ	SMBV100A	260452	9kHz to 6GHz	8/24/2018	8/24/2019
MDC26	MULTIMETER (JAVIER)	FLUKE	179	34720014	I;VDC;VAC;R	8/29/2018	8/29/2019
NTA3	BILOG ANTENNA	TESEQ	6112D	32853	25-1000MHz	10/3/2018	10/3/2019
NWQ0	DOUBLE RIDGED WAVEGUIDE ANTENNA	ETS LINDGREN	3117	66657	1GHZ-18GHZ	5/31/2018	5/31/2020
RBG0	EMI ANALYZER	ROHDE & SCHWARZ	ESW44	101533	10HZ-44GHZ	12/5/2018	12/5/2019
RBG3	EMI ANALYZER	ROHDE & SCHWARZ	ESW44	101592	2HZ-44GHZ	2/20/2019	2/20/2020
T1N6	10DB 20W ATTENUATOR	NARDA	766-10	---	DC-4GHZ	5/14/2018	5/14/2020
T2D5	20DB, 25W ATTENUATOR	WEINSCHEL	46-20-43	AY9244	DC-18GHZ	5/14/2018	5/14/2020
VBV2	CISPR EN FCC ICES RE.EXE	ELITE	CISPR EN FCC ICES RE.EXE	---	---	N/A	
WKA1	SOFTWARE, UNIVERSAL RCV EMI	ELITE	UNIV_RCV_EMI	1	---	I/O	
XPQ3	HIGH PASS FILTER	K&L MICROWAVE	4IH30-1804/T10000-0	4	1.8GHZ-10GHZ	9/12/2017	9/12/2019
XPQ4	HIGH PASS FILTER	K&L MICROWAVE	11SH10-4800/X20000-O/O	1	4.8-20GHZ	9/12/2017	9/12/2019

I/O – Initial Only
N/A – Not Applicable

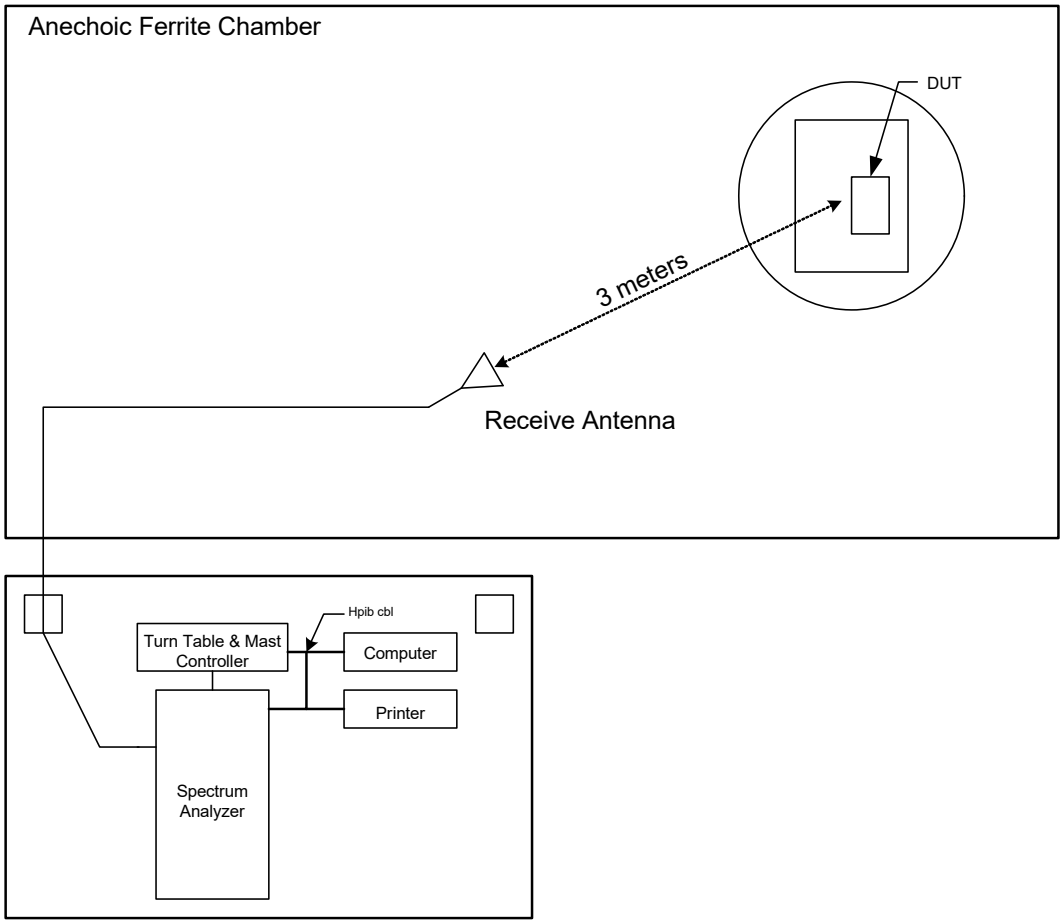


FIGURE 1 BLOCKDIAGRAM OF TEST SETUP

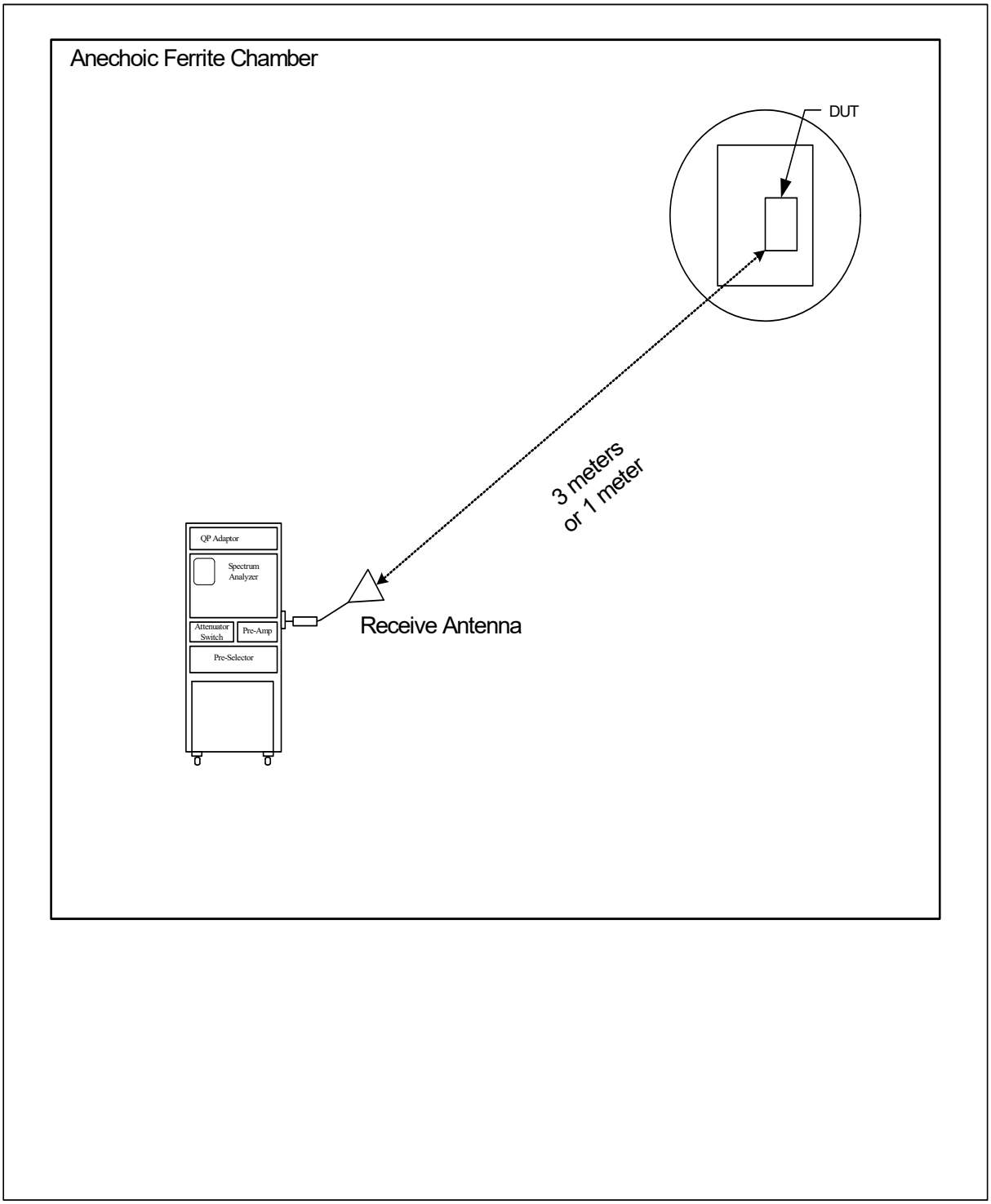
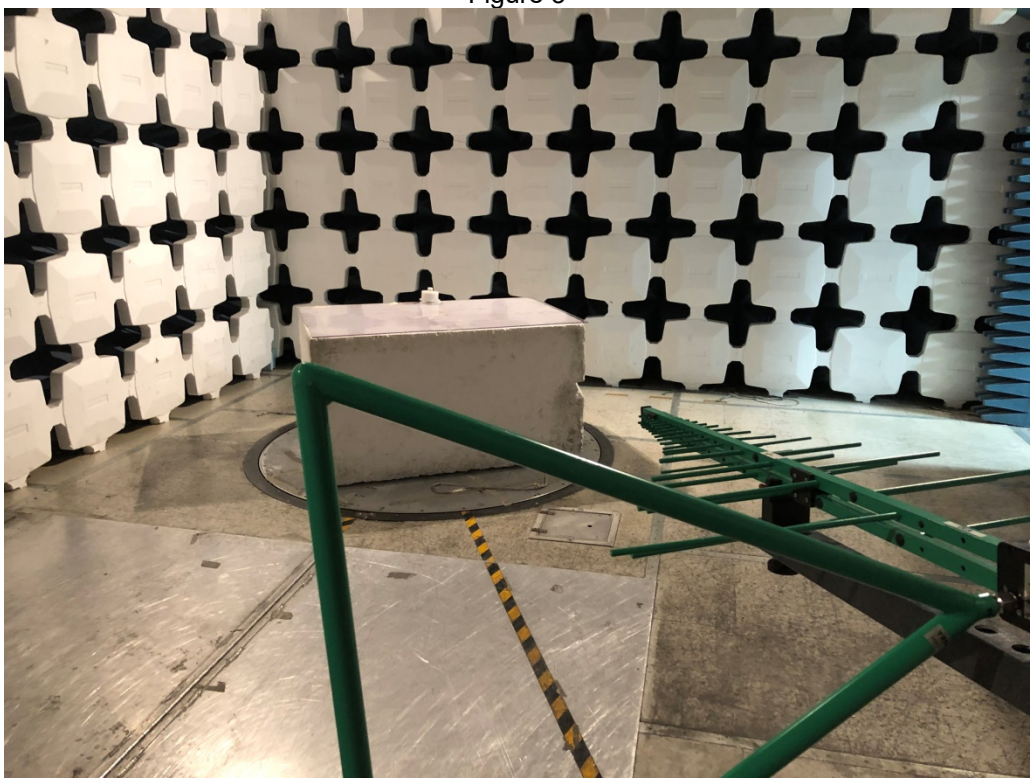


Figure 2: BLOCK DIAGRAM OF TEST SETUP FOR RADIATED EMISSIONS ABOVE 18GHZ

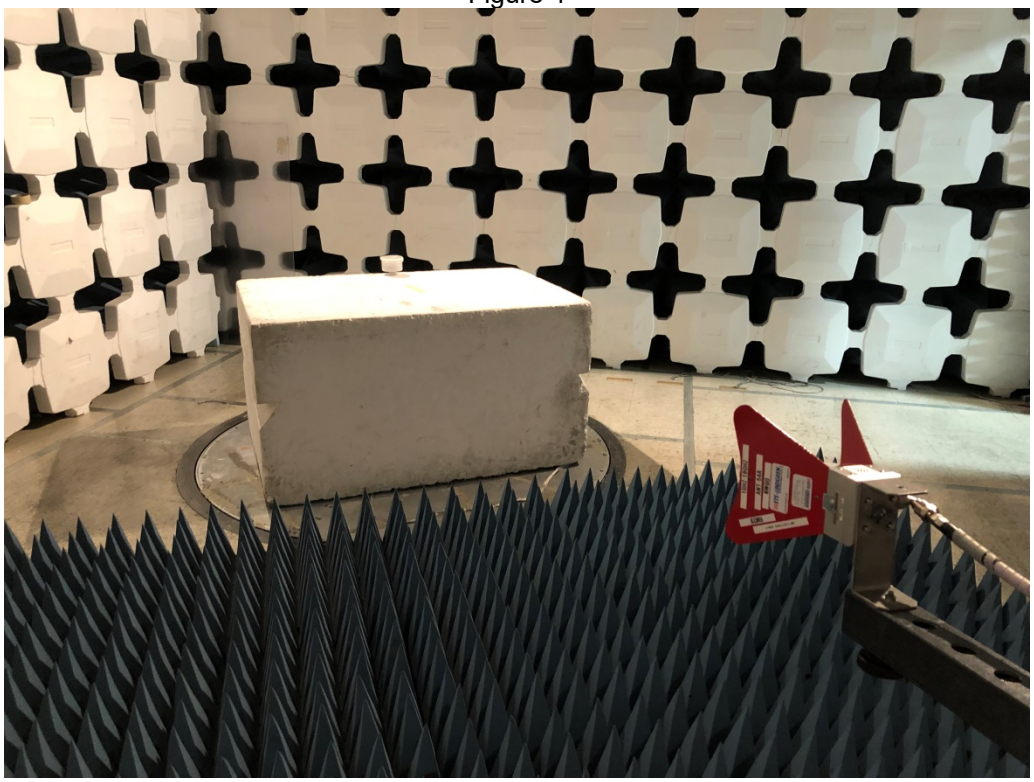
Figure 3



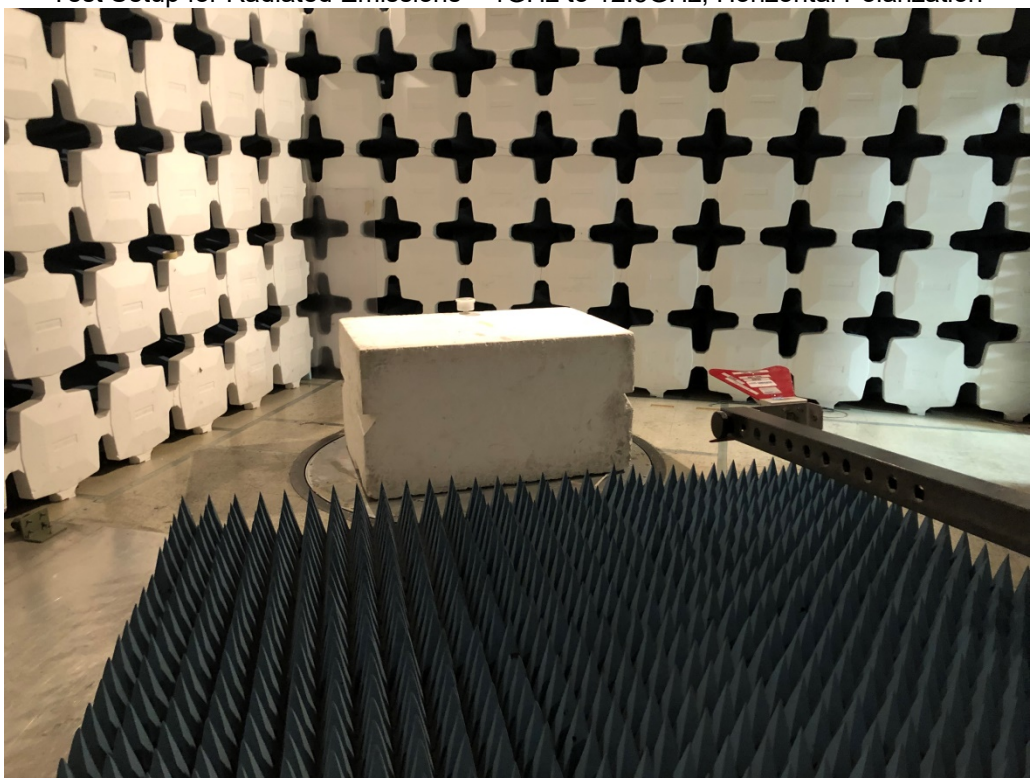
Test Setup for Radiated Emissions – 30MHz to 1GHz, Horizontal Polarization

Test Setup for Radiated Emissions – 30MHz to 1GHz, Vertical Polarization

Figure 4



Test Setup for Radiated Emissions – 1GHz to 12.5GHz, Horizontal Polarization



Test Setup for Radiated Emissions – 1GHz to 12.5GHz, Vertical Polarization

FCC Part 15B Class A Radiated RF Emissions Test

SW ID/Rev: VBV2 01/02/2019

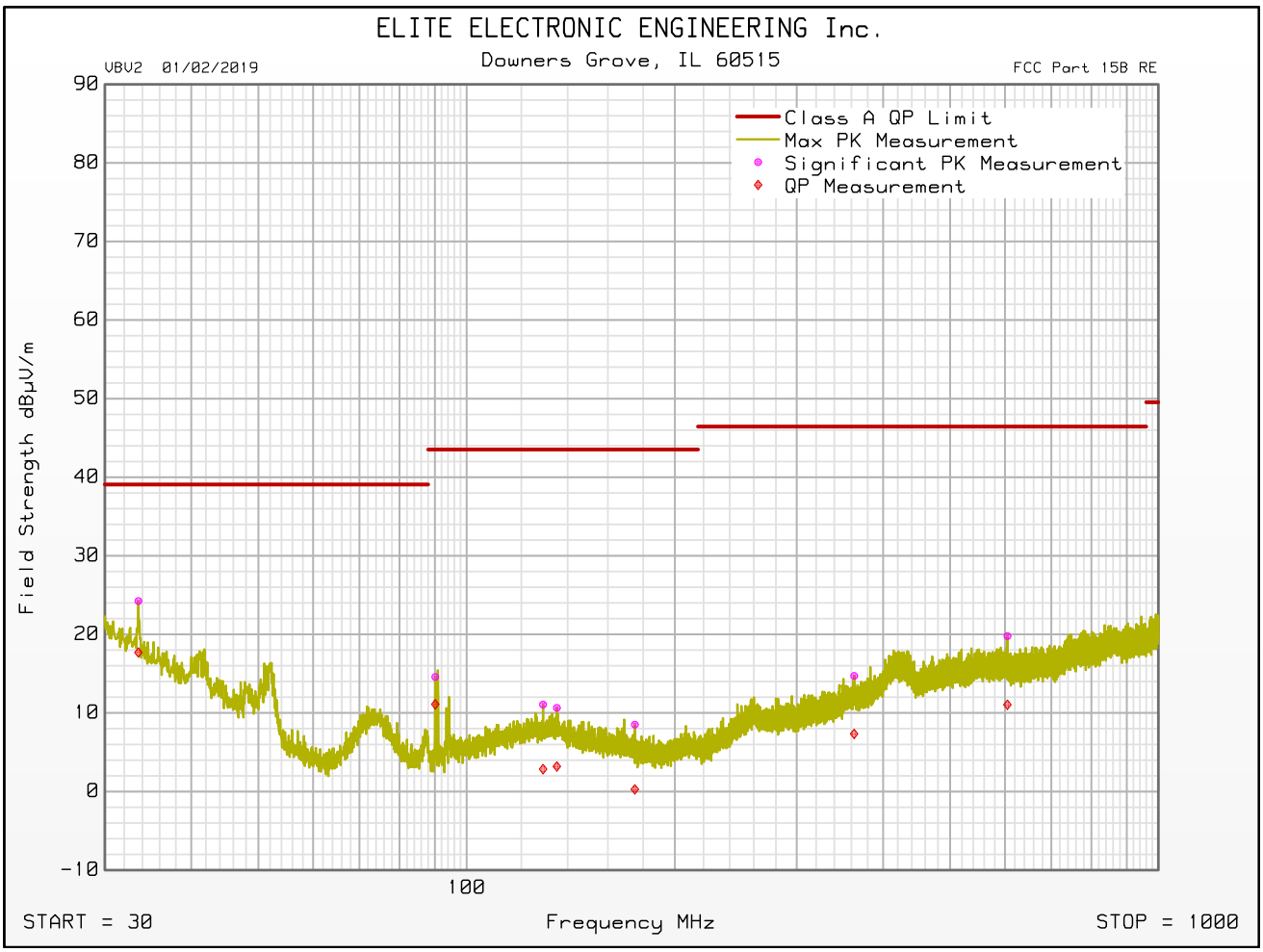
Manufacturer : Creative Electronics and Software Inc
Model : 100-00
Serial Number : 0009018523
DUT Mode : Idle
Turntable Step Angle (°): 45
Mast Positions (cm) : 120, 200, 340
Scan Type : Stepped Scan
Test RBW : 120 kHz
Prelim Dwell Time (s) : 0.0001
Notes :
Test Engineer : J. Cardenas
Test Date : Jun 21, 2019 12:16:00 PM

Freq MHz	Peak Mtr Rdg dBuV	QP Mtr Rdg dBuV	Ant Fac dB	Amp Fac dB	Cbl Fac dB	Dist Corr dB	Peak Total dBµV/m	QP Total dBµV/m	QP Limit dBµV/m	QP Lim Mrg dB	Ant Pol	Mast Ht cm	Azim °
33.540	7.5	0.9	26.7	0.0	0.5	-10.5	24.2	17.7	39.1	-21.4	V	340	135
40.620	6.1	-1.2	23.2	0.0	0.5	-10.5	19.3	12.1	39.1	-27.0	H	340	45
52.320	10.5	4.4	17.4	0.0	0.5	-10.5	18.0	11.9	39.1	-27.2	H	340	180
72.540	2.3	-5.4	19.7	0.0	0.5	-10.5	12.1	4.4	39.1	-34.7	H	120	135
90.100	10.5	7.1	14.0	0.0	0.5	-10.5	14.6	11.1	43.5	-32.4	V	120	135
90.940	11.7	8.3	14.1	0.0	0.5	-10.5	15.8	12.4	43.5	-31.2	H	120	270
93.520	8.2	4.1	14.6	0.0	0.5	-10.5	12.8	8.8	43.5	-34.8	H	200	180
128.980	2.3	-5.9	18.6	0.0	0.7	-10.5	11.1	2.9	43.5	-40.7	V	340	45
135.040	1.6	-5.8	18.8	0.0	0.7	-10.5	10.6	3.2	43.5	-40.3	V	340	0
175.060	2.4	-5.8	15.7	0.0	0.9	-10.5	8.5	0.3	43.5	-43.2	V	120	135
280.620	3.9	-5.1	18.7	0.0	1.0	-10.5	13.2	4.2	46.4	-42.3	H	120	45
363.240	3.1	-4.3	20.7	0.0	1.3	-10.5	14.7	7.3	46.4	-39.1	V	120	180
423.900	5.7	-1.7	22.2	0.0	1.5	-10.5	18.9	11.5	46.4	-34.9	H	200	180
604.920	4.2	-4.5	24.5	0.0	1.5	-10.5	19.8	11.0	46.4	-35.4	V	120	270
773.400	4.0	-4.5	25.7	0.0	1.9	-10.5	21.2	12.8	46.4	-33.7	H	340	90
929.340	4.4	-3.6	26.4	0.0	2.0	-10.5	22.4	14.4	46.4	-32.0	H	200	180

FCC Part 15B Class A Radiated RF Emissions Test

SW ID/Rev: VBV2 01/02/2019

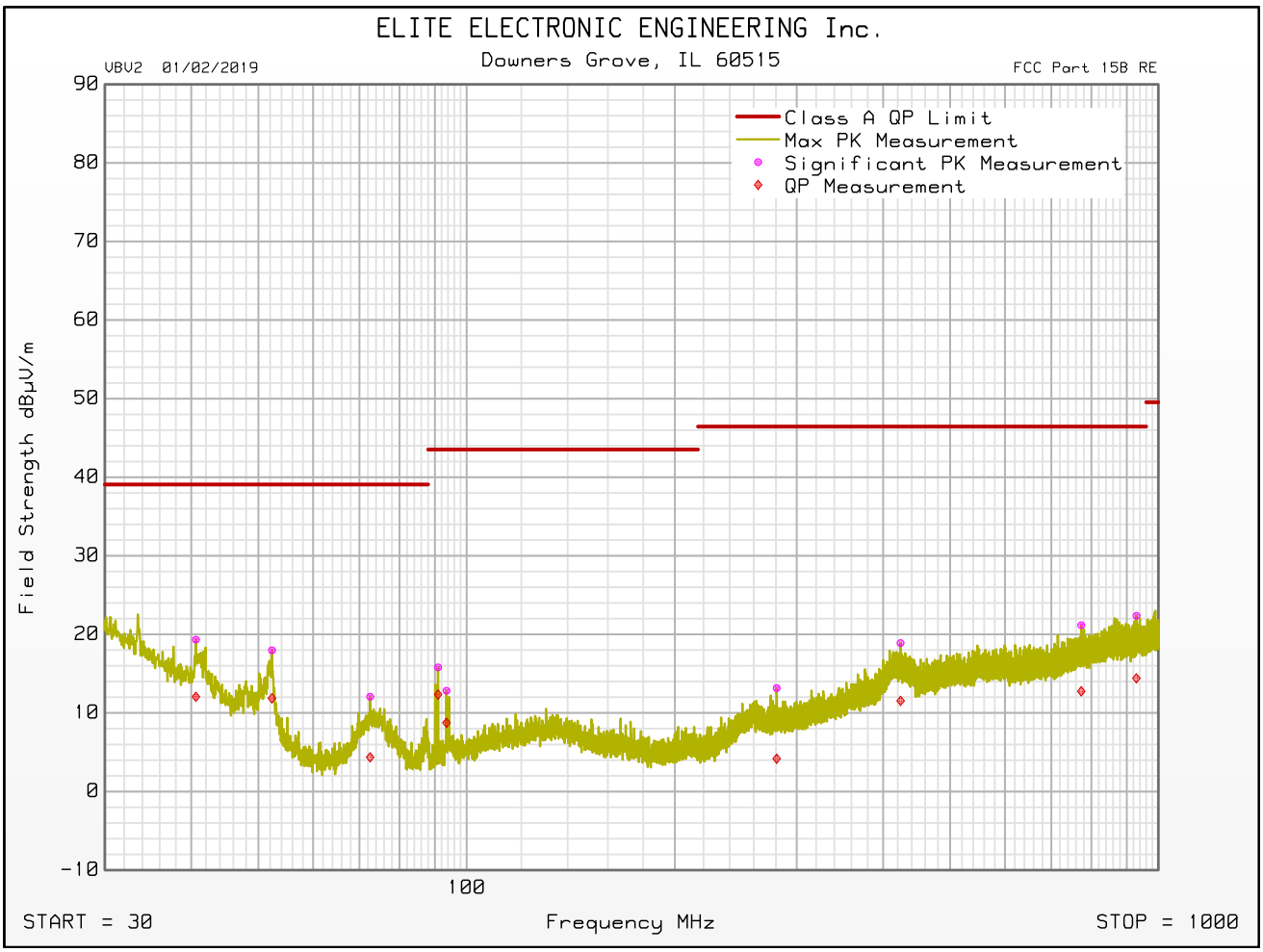
Manufacturer	:	Creative Electronics and Software Inc
Model	:	100-00
Serial Number	:	0009018523
DUT Mode	:	Idle
Turntable Step Angle (°)	:	45
Mast Positions (cm)	:	120, 200, 340
Ant. Polarization(s)	:	V
Scan Type	:	Stepped Scan
Test RBW	:	120 kHz
Prelim Dwell Time (s)	:	0.0001
Notes	:	
Test Engineer	:	J. Cardenas
Test Date	:	Jun 21, 2019 12:16:00 PM



FCC Part 15B Class A Radiated RF Emissions Test

SW ID/Rev: VBV2 01/02/2019

Manufacturer	:	Creative Electronics and Software Inc
Model	:	100-00
Serial Number	:	0009018523
DUT Mode	:	Idle
Turntable Step Angle (°)	:	45
Mast Positions (cm)	:	120, 200, 340
Ant. Polarization(s)	:	H
Scan Type	:	Stepped Scan
Test RBW	:	120 kHz
Prelim Dwell Time (s)	:	0.0001
Notes	:	
Test Engineer	:	J. Cardenas
Test Date	:	Jun 21, 2019 12:16:00 PM



FCC Part 15B Class A Radiated RF Emissions Test

SW ID/Rev: VBV2 01/02/2019

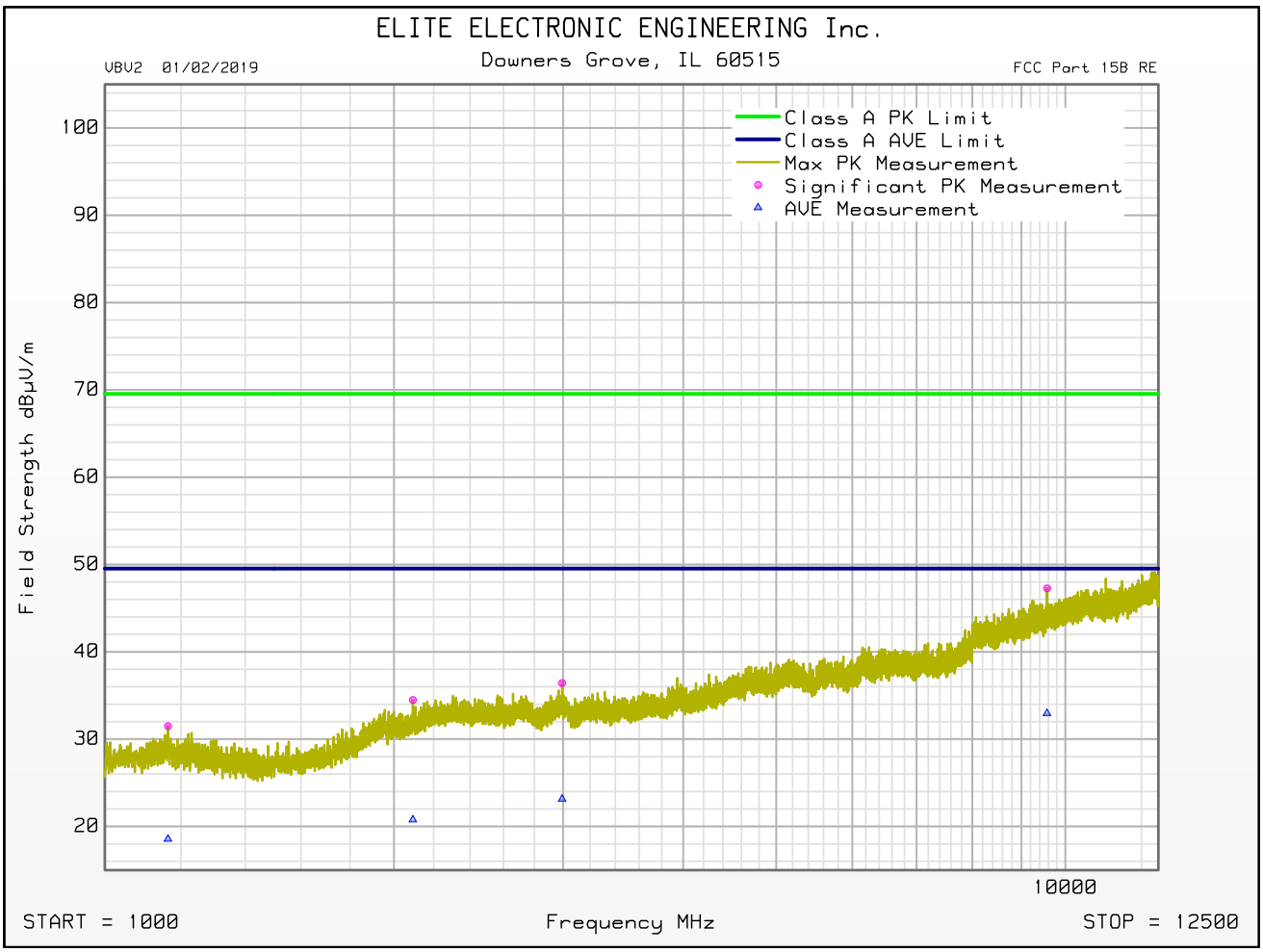
Manufacturer : Creative Electronics and Software Inc.
Model : 100-00
Serial Number : 0009018523
DUT Mode : Idle
Turntable Step Angle (°): 45
Mast Positions (cm) : 120, 200, 340
Scan Type : Stepped Scan
Test RBW : 1 MHz
Prelim Dwell Time (s) : 0.0001
Notes :
Test Engineer : J. Cardenas
Test Date : Jun 25, 2019 02:13:14 PM

Freq MHz	Peak Mtr Rdg dBuV	Average Mtr Rdg dBuV	Ant Fac dB	Amp Fac dB	Cbl Fac dB	Dist Corr dB	Peak Total dBµV/m	Peak Limit dBµV/m	Peak Lim Mrg dB	Average Total dBµV/m	Average Limit dBµV/m	Average Lim Mrg dB	Ant Pol	Mast Ht cm	Azim °
1163.500	51.0	38.1	29.8	-41.1	2.2	-10.5	31.5	69.5	-38.1	18.6	49.5	-31.0	V	120	270
1633.500	49.4	36.5	29.5	-41.1	2.7	-10.5	30.1	69.5	-39.5	17.1	49.5	-32.4	H	120	315
2092.500	49.1	35.3	33.0	-40.2	3.1	-10.5	34.5	69.5	-35.1	20.8	49.5	-28.8	V	340	315
2720.000	49.4	36.0	33.6	-40.3	3.7	-10.5	35.9	69.5	-33.6	22.5	49.5	-27.0	H	200	180
2993.000	48.9	35.6	34.5	-40.4	3.9	-10.5	36.4	69.5	-33.1	23.1	49.5	-26.4	V	200	135
4472.500	47.6	34.4	36.0	-39.9	4.8	-10.5	38.0	69.5	-31.6	24.8	49.5	-24.8	H	340	315
5090.500	47.6	34.2	37.6	-40.2	5.0	-10.5	39.6	69.5	-29.9	26.3	49.5	-23.3	H	200	270
7135.000	47.7	33.8	37.9	-39.8	6.1	-10.5	41.4	69.5	-28.1	27.5	49.5	-22.0	H	340	45
9570.000	50.5	36.2	39.2	-38.8	6.8	-10.5	47.3	69.5	-22.3	33.0	49.5	-16.6	V	120	315
12385.000	49.4	36.2	41.9	-39.3	8.0	-10.5	49.5	69.5	-20.0	36.3	49.5	-13.2	H	340	180

FCC Part 15B Class A Radiated RF Emissions Test

SW ID/Rev: VBV2 01/02/2019

Manufacturer	:	Creative Electronics and Software Inc.
Model	:	100-00
Serial Number	:	0009018523
DUT Mode	:	Idle
Turntable Step Angle (°)	:	45
Mast Positions (cm)	:	120, 200, 340
Ant. Polarization(s)	:	V
Scan Type	:	Stepped Scan
Test RBW	:	1 MHz
Prelim Dwell Time (s)	:	0.0001
Notes	:	
Test Engineer	:	J. Cardenas
Test Date	:	Jun 25, 2019 02:13:14 PM



FCC Part 15B Class A Radiated RF Emissions Test

SW ID/Rev: VBV2 01/02/2019

Manufacturer	:	Creative Electronics and Software Inc.
Model	:	100-00
Serial Number	:	0009018523
DUT Mode	:	Idle
Turntable Step Angle (°)	:	45
Mast Positions (cm)	:	120, 200, 340
Ant. Polarization(s)	:	H
Scan Type	:	Stepped Scan
Test RBW	:	1 MHz
Prelim Dwell Time (s)	:	0.0001
Notes	:	
Test Engineer	:	J. Cardenas
Test Date	:	Jun 25, 2019 02:13:14 PM

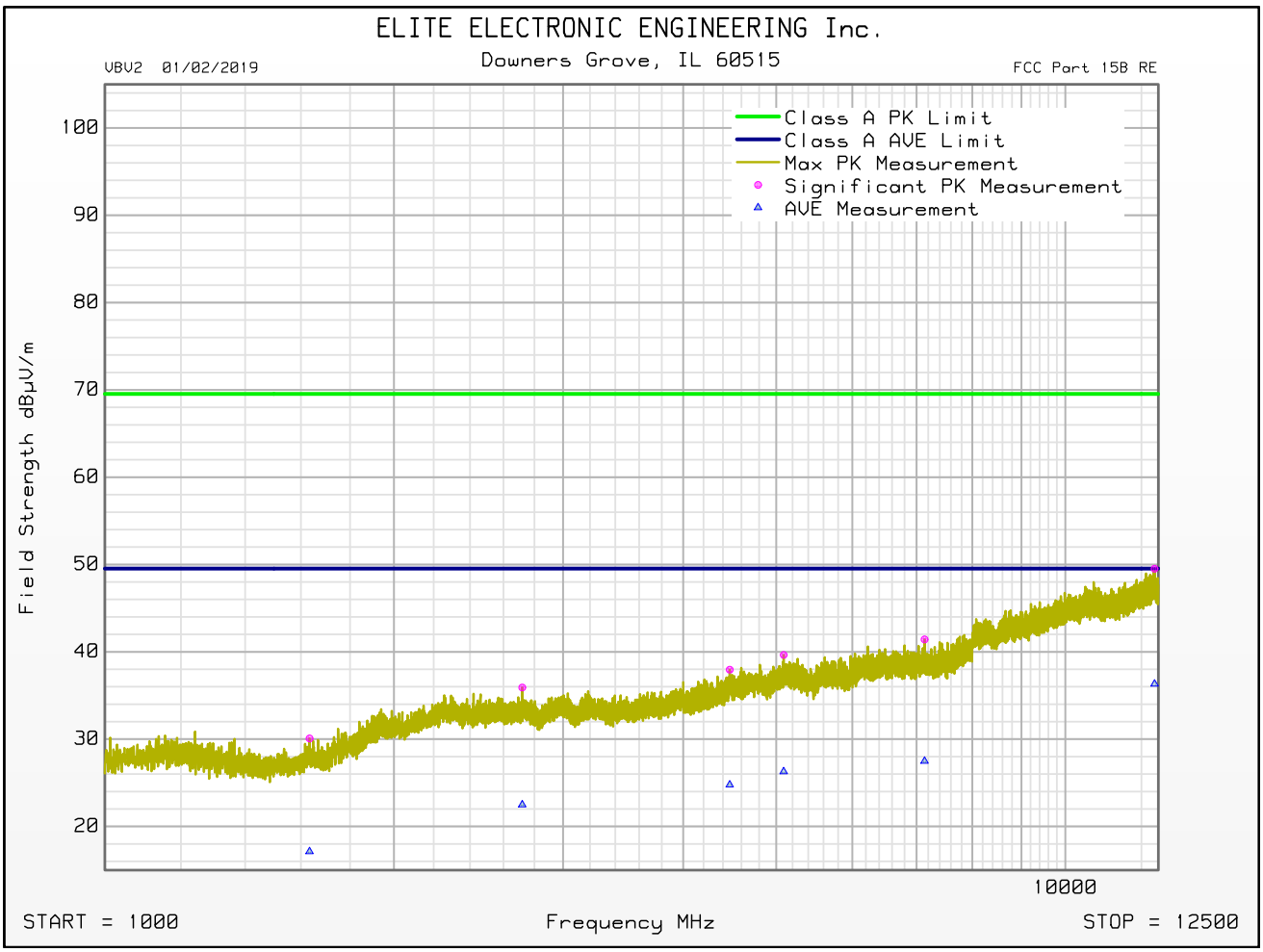
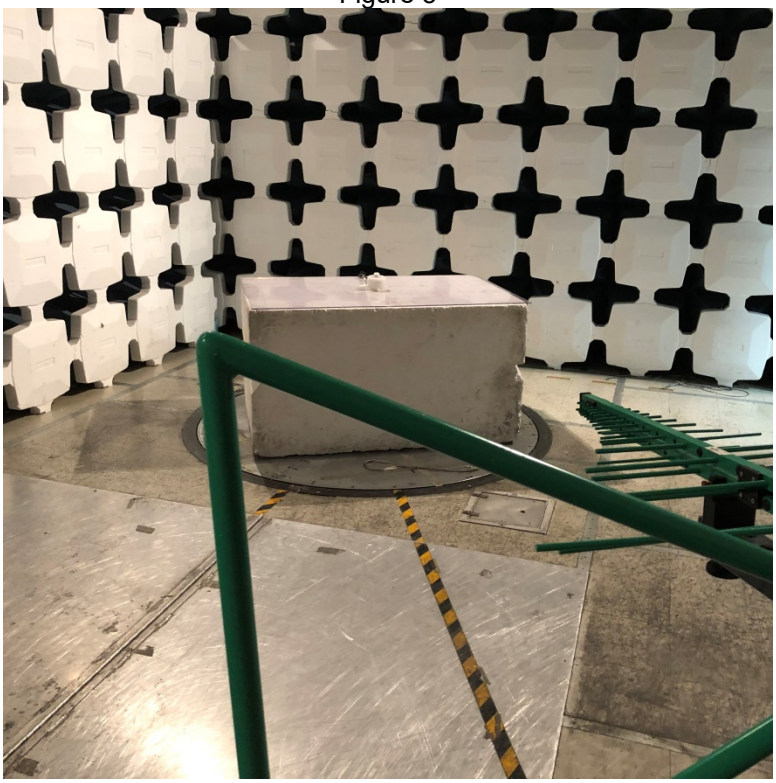


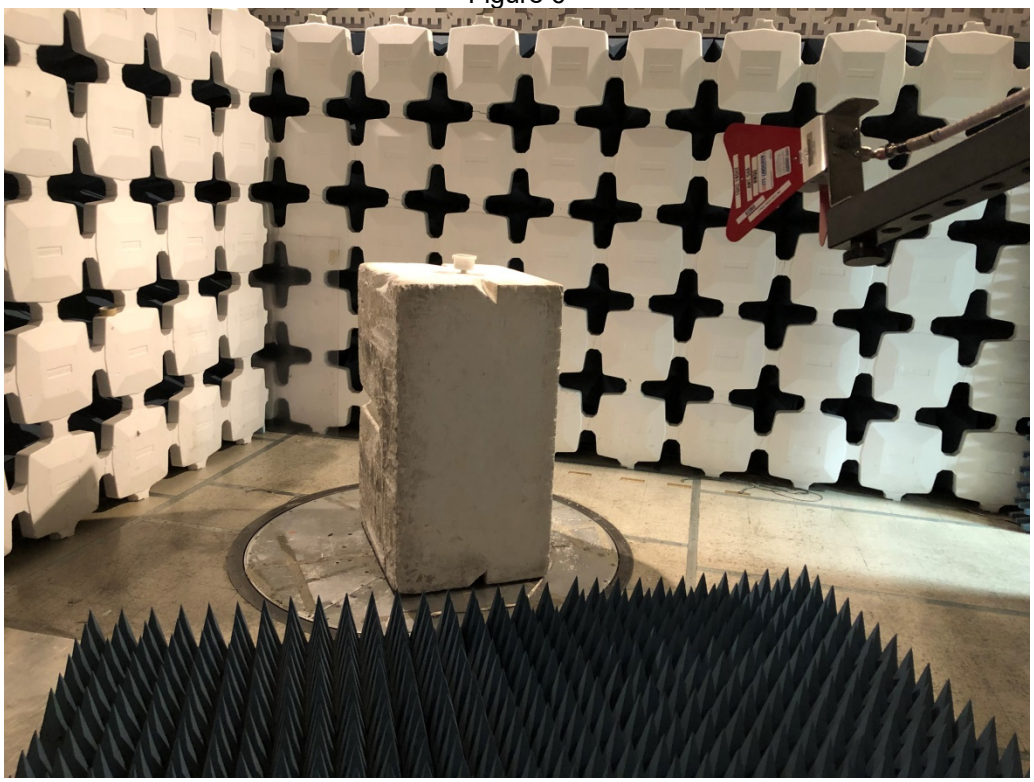
Figure 5



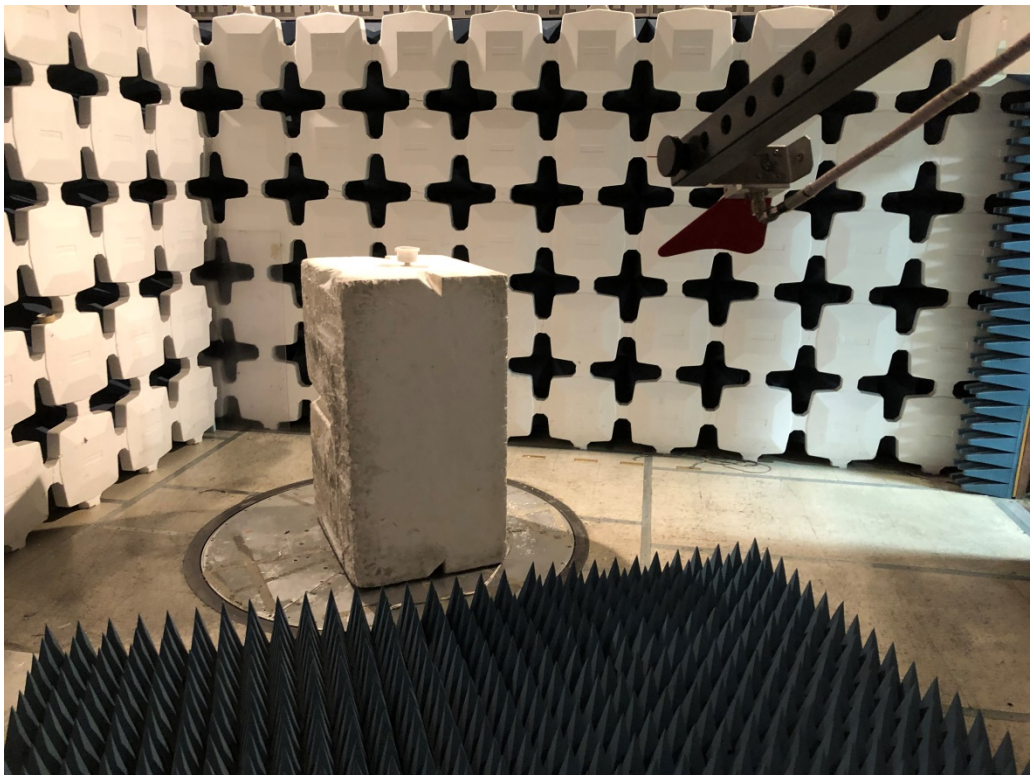
Test Setup for Spurious Radiated Emissions – 30MHz to 1GHz, Horizontal Polarization

Test Setup for Spurious Radiated Emissions – 30MHz to 1GHz, Vertical Polarization

Figure 6

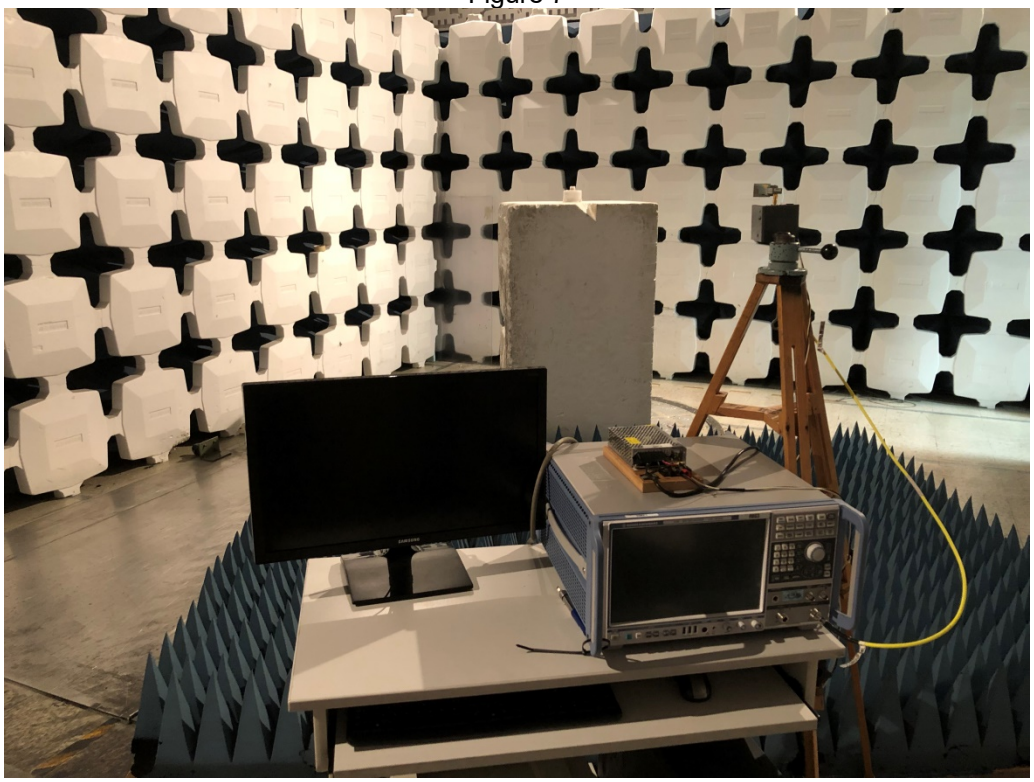


Test Setup for Spurious Radiated Emissions – 1GHz to 12.5GHz, Horizontal Polarization

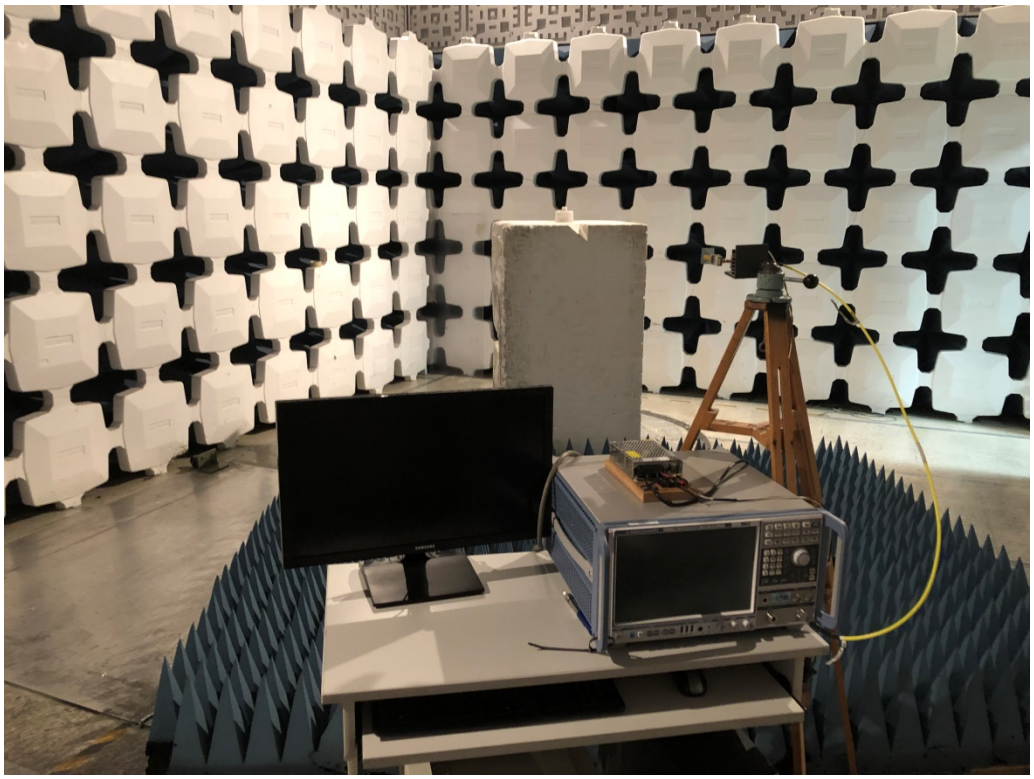


Test Setup for Spurious Radiated Emissions – 1GHz to 12.5GHz, Vertical Polarization

Figure 7

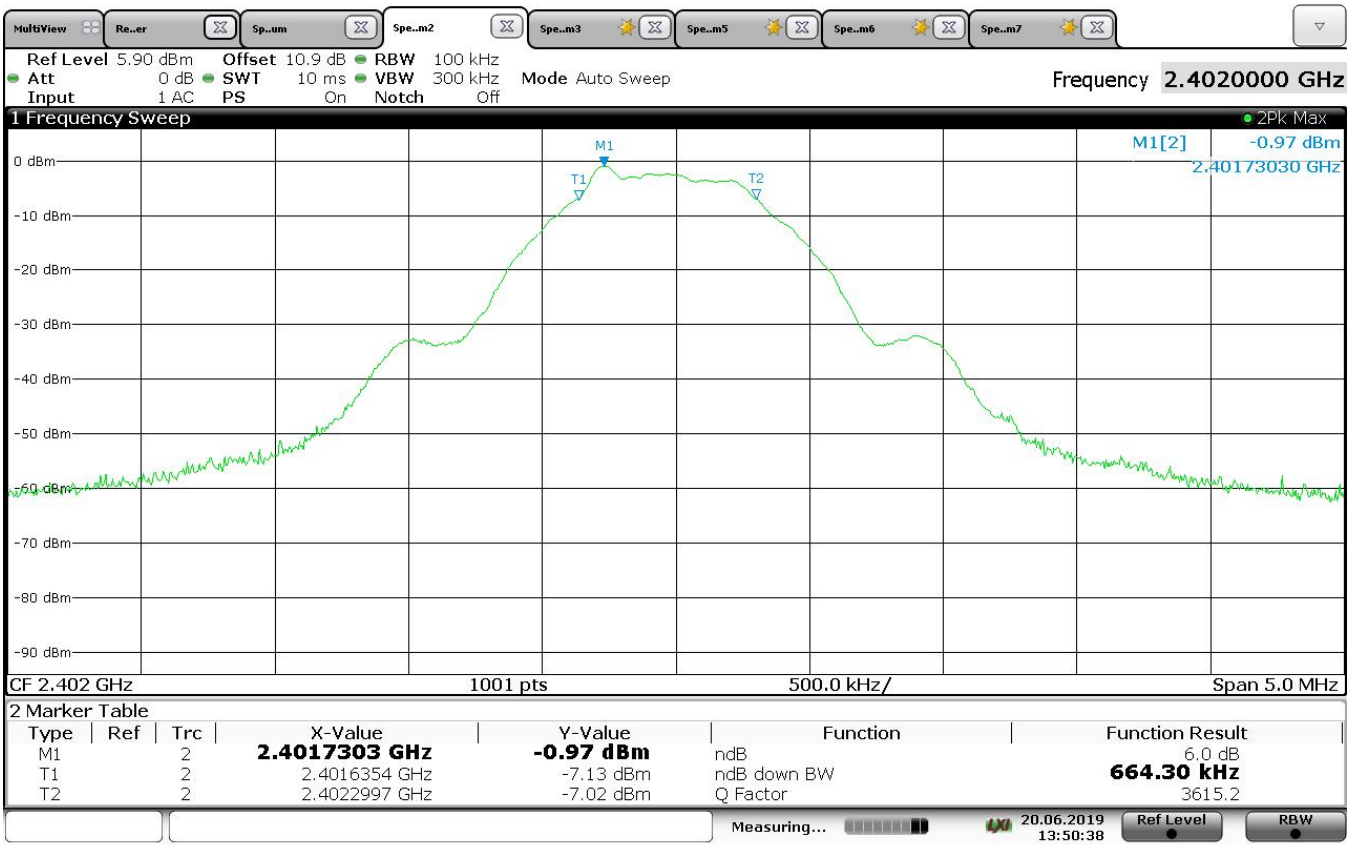


Test Setup for Spurious Radiated Emissions – 18GHz to 26.5GHz, Horizontal Polarization



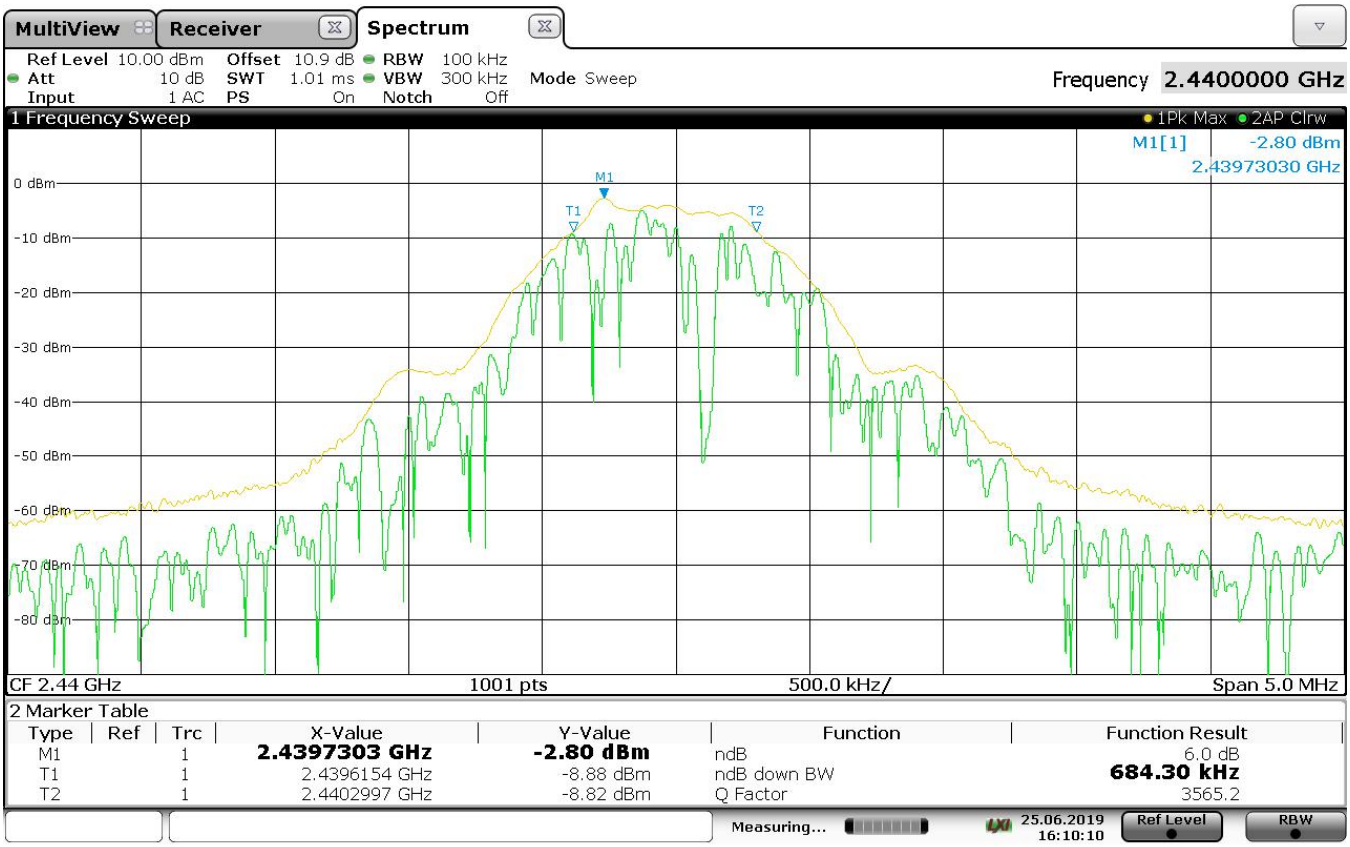
Test Setup for Spurious Radiated Emissions – 18GHz to 26.5GHz, Vertical Polarization

DTS 6dB Bandwidth



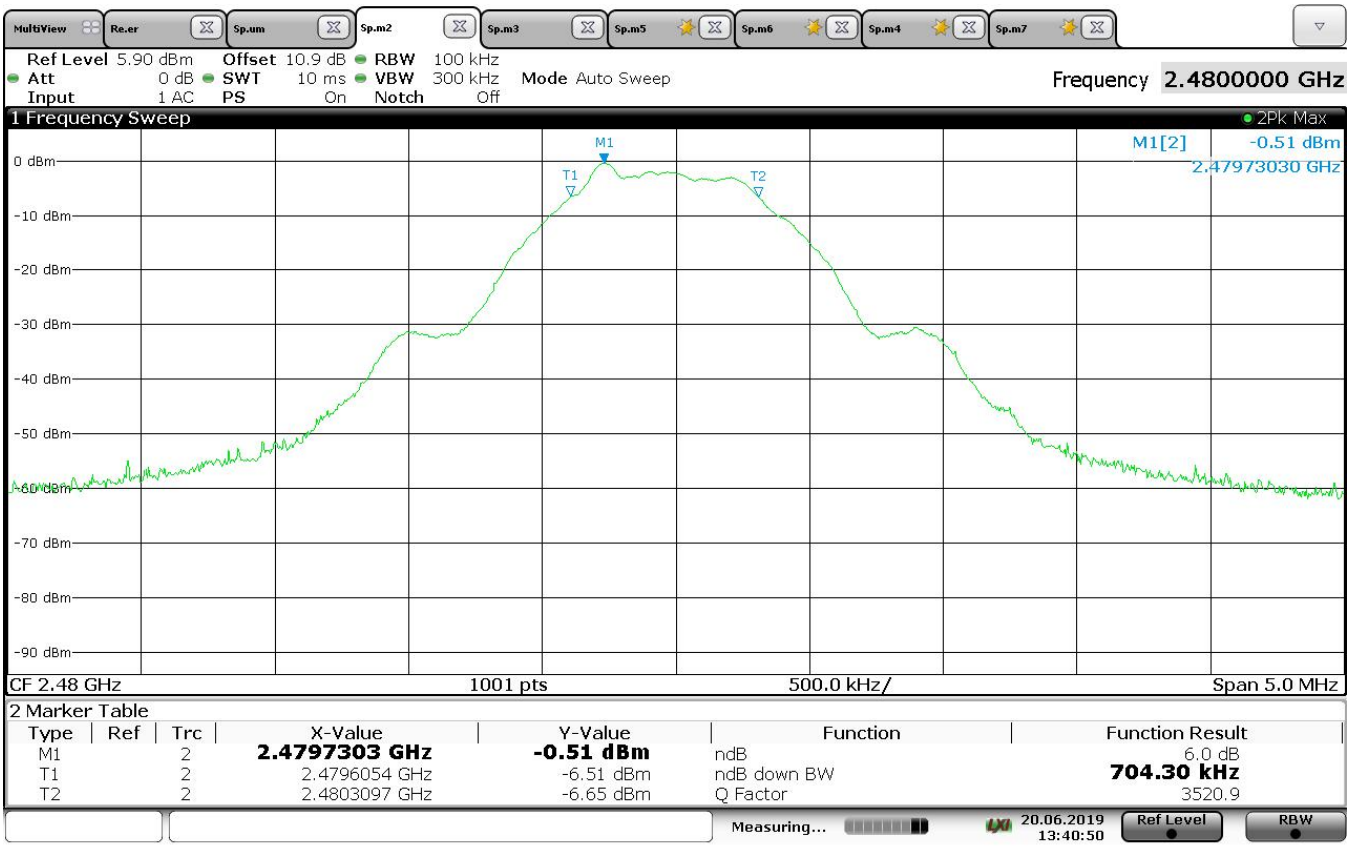
13:50:38 20.06.2019

Manufacturer : Creative Electronics and Software, Inc.
Model Number : 100-00
Serial Number : 0009018523
Test : **DTS 6dB Bandwidth**
Mode : BLE Tx 2402MHz
Parameters : DTS 6dB BW = **664.3kHz**
Date : June 21-25,2019
Notes :



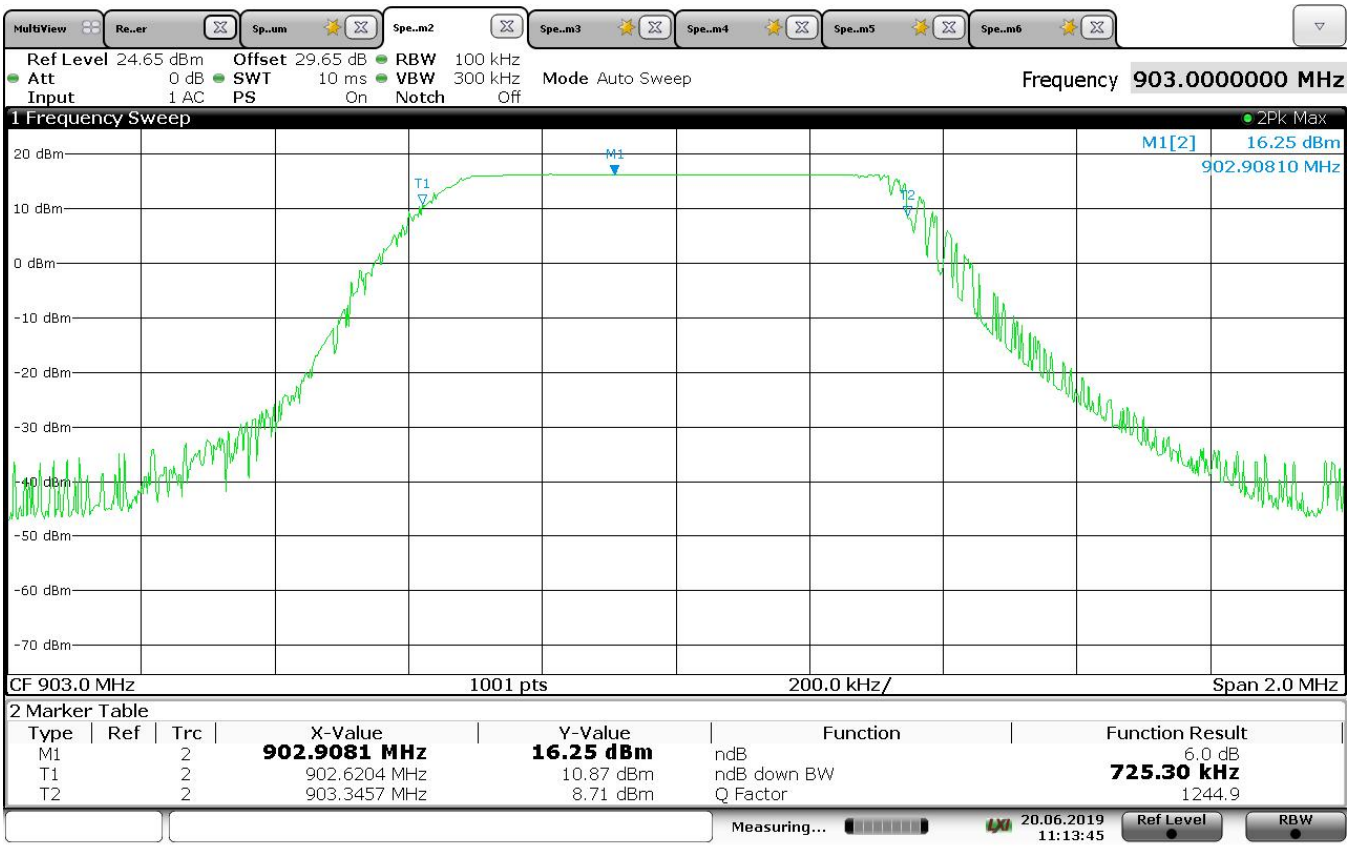
16:10:10 25.06.2019

Manufacturer : Creative Electronics and Software, Inc.
Model Number : 100-00
Serial Number : 0009018523
Test : **DTS 6dB Bandwidth**
Mode : BLE Tx 2440MHz
Parameters : DTS 6dB BW = **684.3kHz**
Date : June 21-25,2019
Notes :



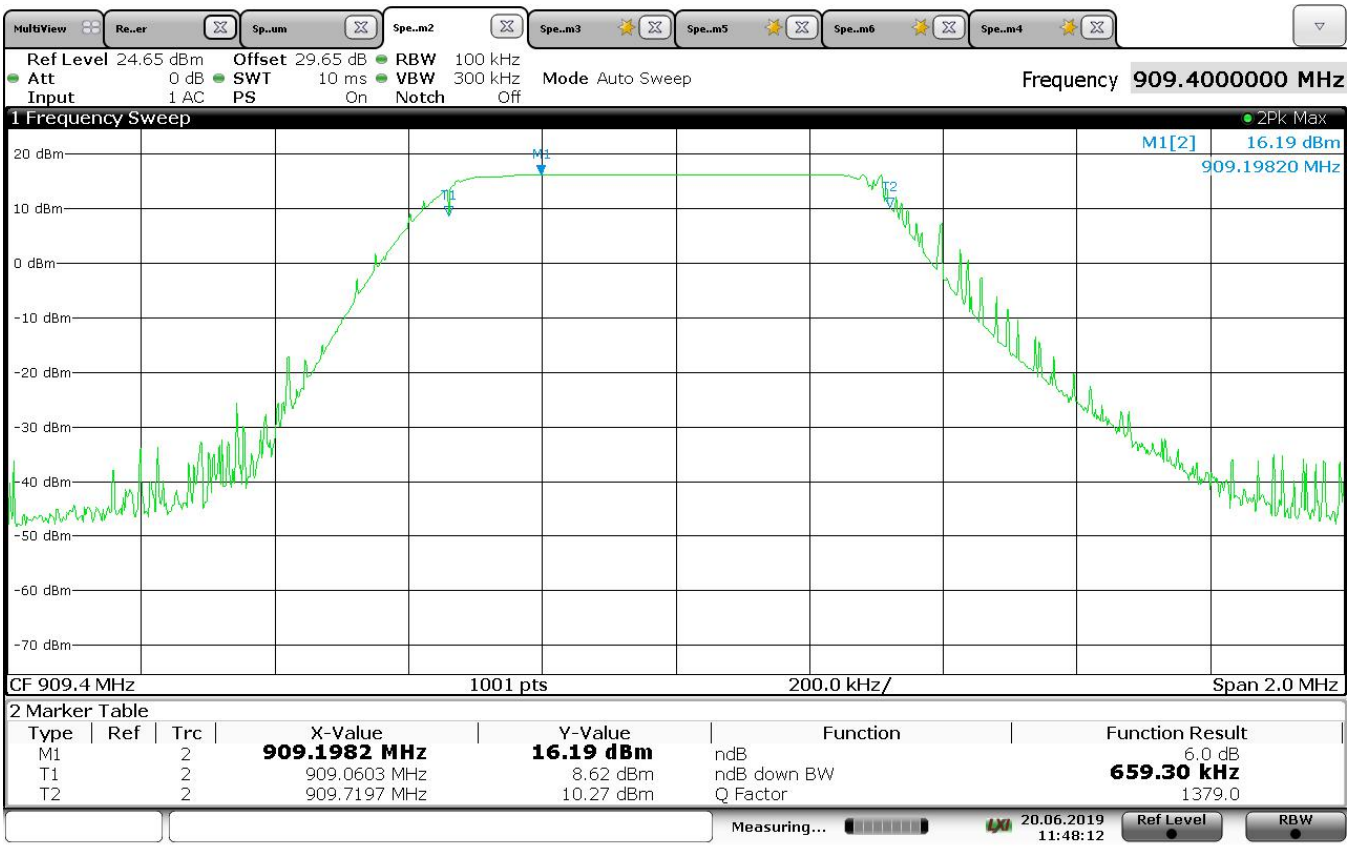
13:40:51 20.06.2019

Manufacturer : Creative Electronics and Software, Inc.
Model Number : 100-00
Serial Number : 0009018523
Test : **DTS 6dB Bandwidth**
Mode : BLE Tx 2480MHz
Parameters : DTS 6dB BW = **704.3kHz**
Date : June 21-25,2019
Notes :



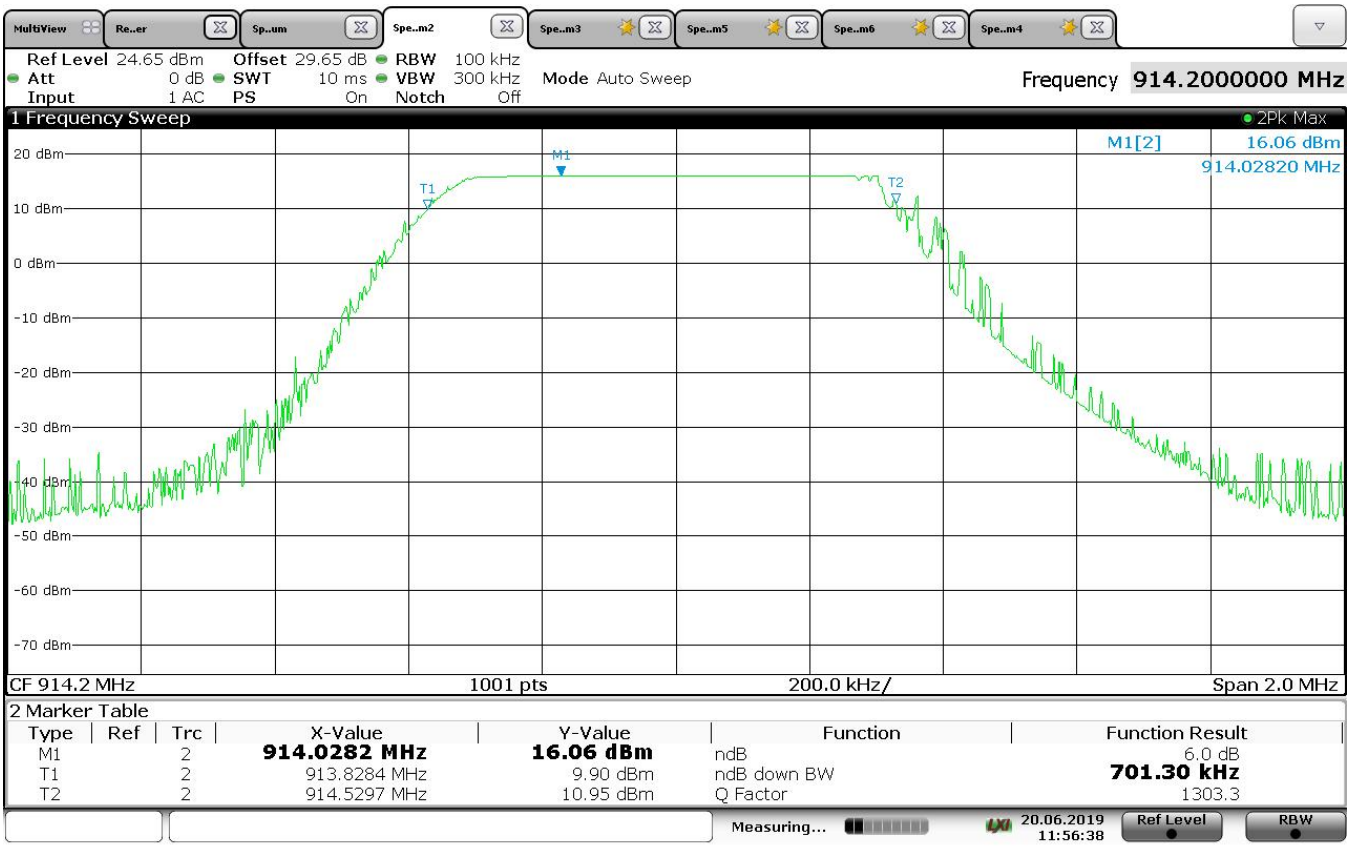
11:13:46 20.06.2019

Manufacturer : Creative Electronics and Software, Inc.
Model Number : 100-00
Serial Number : 0009018523
Test : **DTS 6dB Bandwidth**
Mode : LoRA Tx 903MHz
Parameters : DTS 6dB BW = **725.3kHz**
Date : June 21-25,2019
Notes : SF8



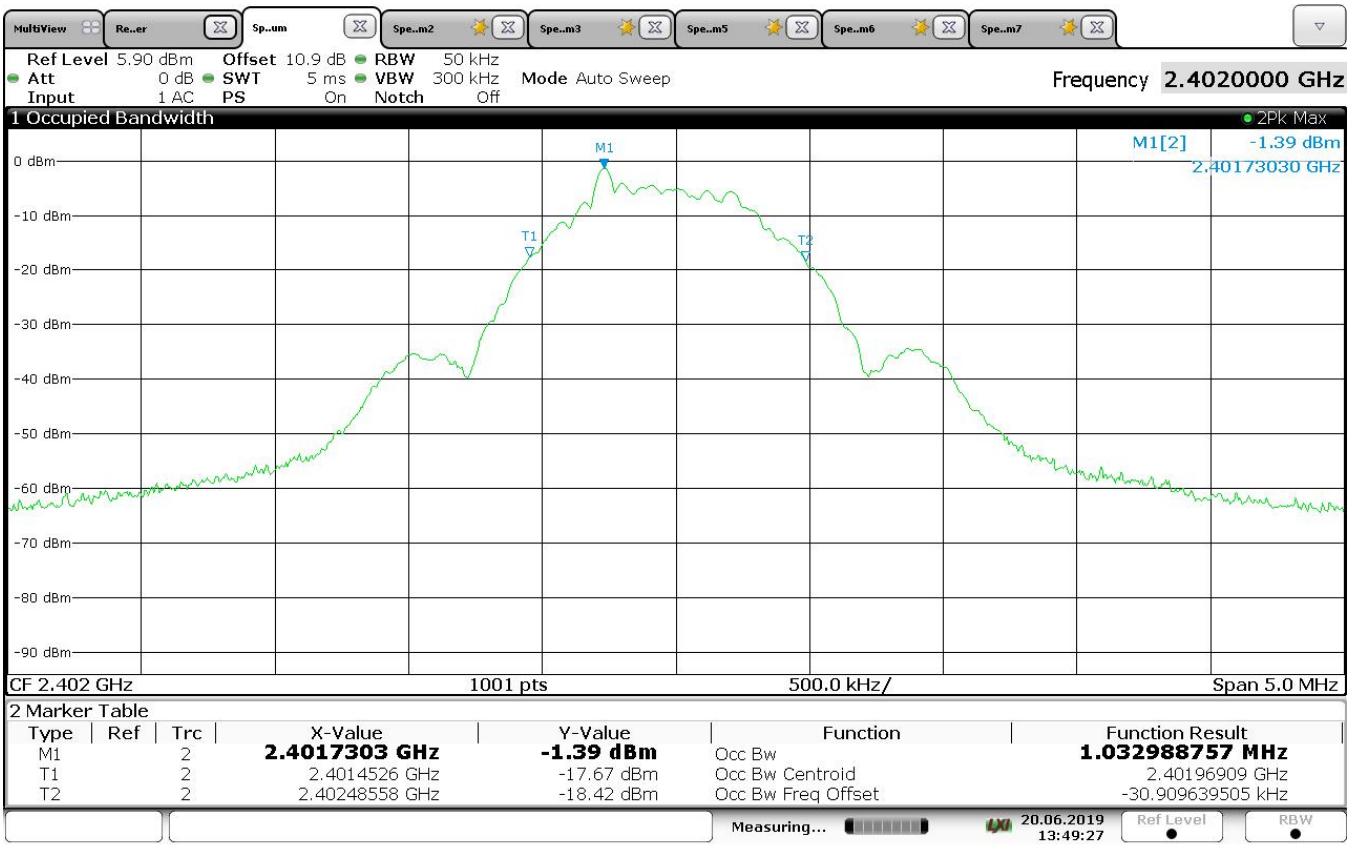
11:48:12 20.06.2019

Manufacturer : Creative Electronics and Software, Inc.
Model Number : 100-00
Serial Number : 0009018523
Test : **DTS 6dB Bandwidth**
Mode : LoRA Tx 909.4MHz
Parameters : DTS 6dB BW = **659.3kHz**
Date : June 21-25,2019
Notes : SF8



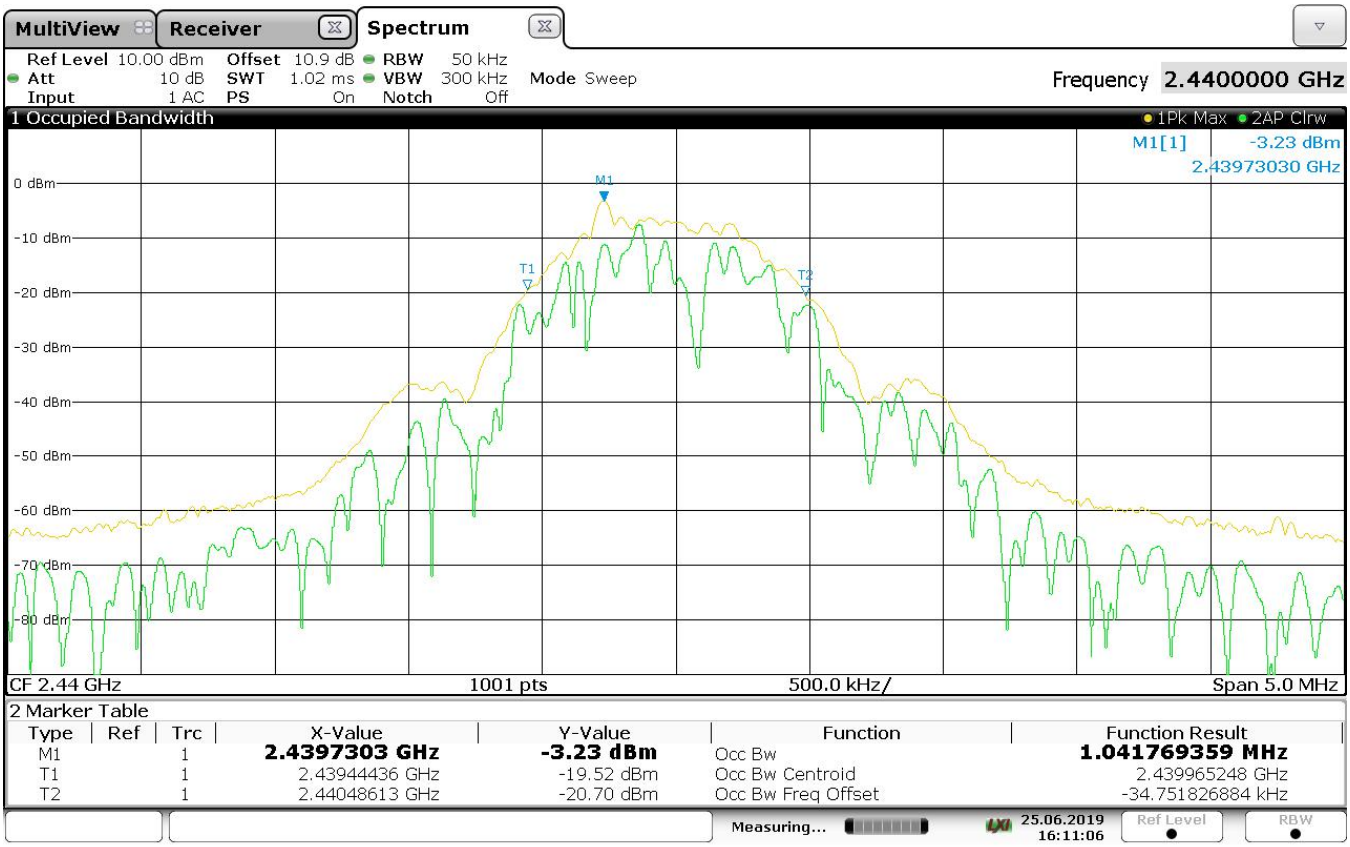
11:56:38 20.06.2019

Manufacturer : Creative Electronics and Software, Inc.
Model Number : 100-00
Serial Number : 0009018523
Test : **DTS 6dB Bandwidth**
Mode : LoRA Tx 914.2MHz
Parameters : DTS 6dB BW = **701.3kHz**
Date : June 21-25,2019
Notes : SF8



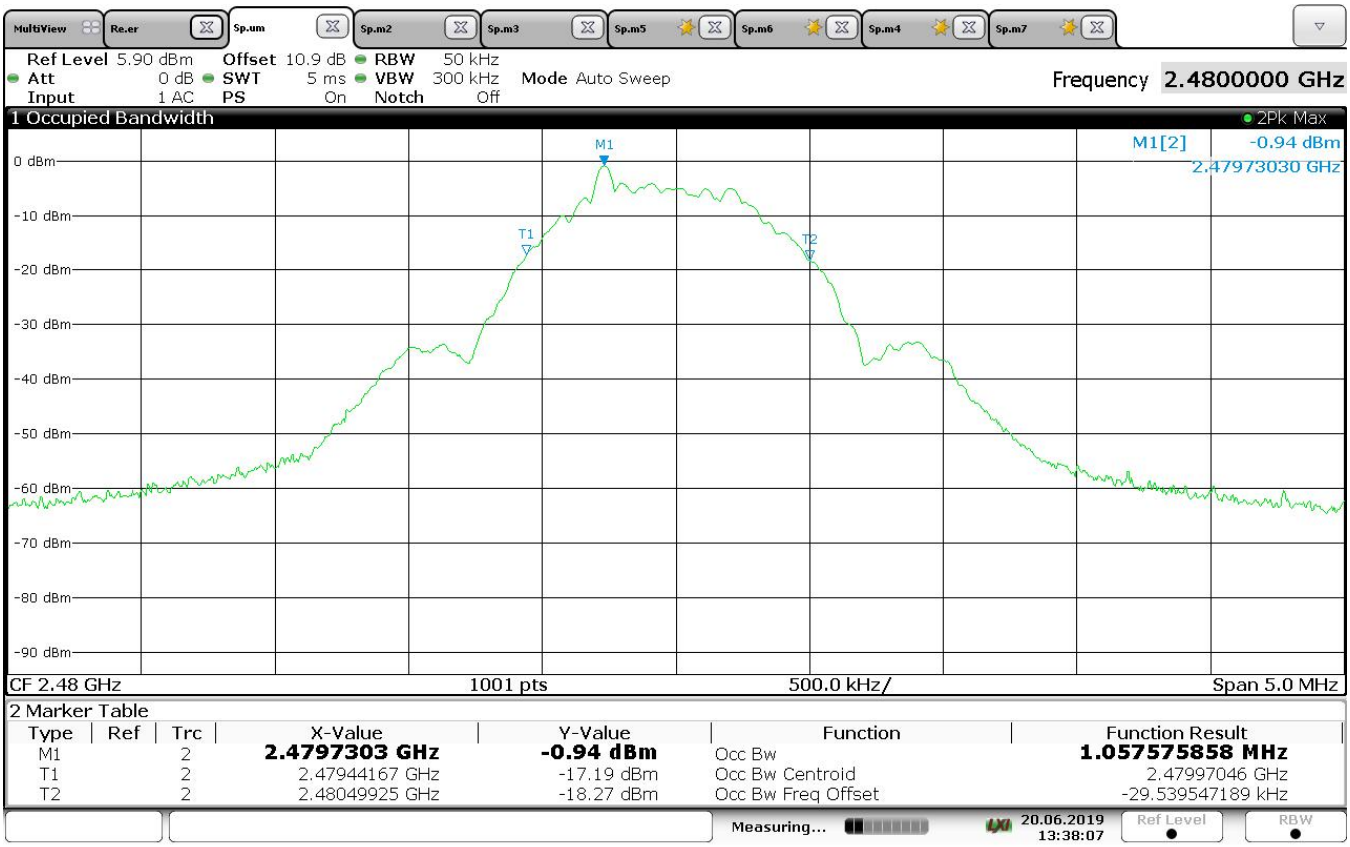
13:49:27 20.06.2019

Manufacturer : Creative Electronics and Software, Inc.
Model Number : 100-00
Serial Number : 0009018523
Test : **99% Occupied Bandwidth**
Mode : BLE Tx 2402MHz
Parameters : 99% BW = **1.03MHz**
Date : June 21-25,2019
Notes :



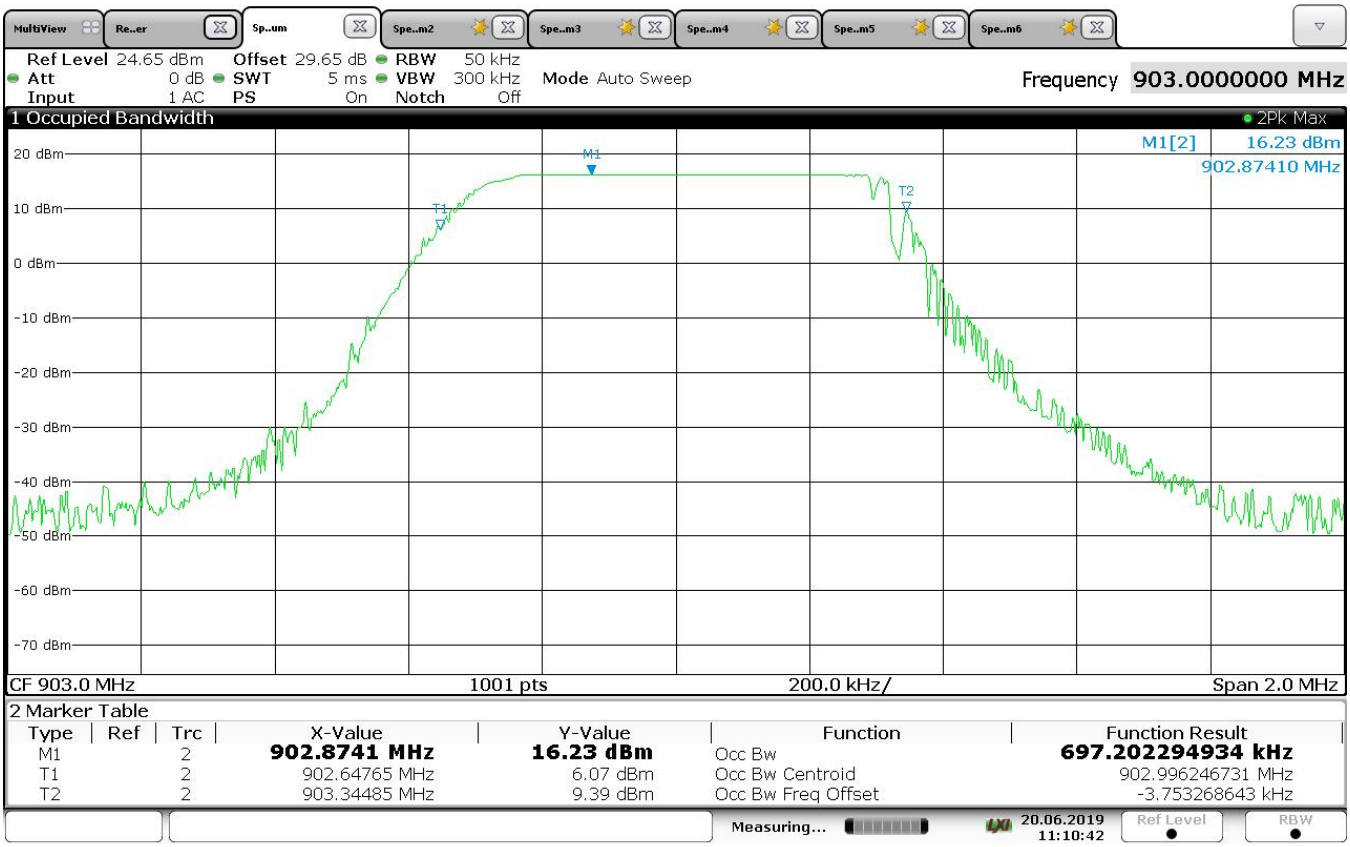
16:11:07 25.06.2019

Manufacturer : Creative Electronics and Software, Inc.
Model Number : 100-00
Serial Number : 0009018523
Test : **99% Occupied Bandwidth**
Mode : BLE Tx 2440MHz
Parameters : 99% BW = **1.04MHz**
Date : June 21-25,2019
Notes :



13:38:07 20.06.2019

Manufacturer : Creative Electronics and Software, Inc.
Model Number : 100-00
Serial Number : 0009018523
Test : **99% Occupied Bandwidth**
Mode : BLE Tx 2480MHz
Parameters : 99% BW = **1.05MHz**
Date : June 21-25,2019
Notes :



11:10:42 20.06.2019

Manufacturer : Creative Electronics and Software, Inc.
Model Number : 100-00
Serial Number : 0009018523
Test : **99% Occupied Bandwidth**
Mode : LoRA Tx 903MHz
Parameters : 99% BW = **697.2kHz**
Date : June 21-25,2019
Notes : SF8